Competence of the assessment method using Q-ray™ system in dental hygiene process

Hye Young Oh

Department of Dentistry

The Graduate School of

Yonsei University

Competence of the assessment method using Q-ray™ system in dental hygiene process

Directed by Professor Baek Il Kim

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Hye Young Oh

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Dissertation of Hye Young Oh is approved.

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Thesis Supervisor: Prof. Baek Il Kim

_____

Thesis Committee: Prof. Ho Keun Kwon

_____

Thesis Committee: Prof. Jong Hoon Choi

_____

Thesis Committee: Prof. Young Sik Cho

_____

Thesis Committee: Prof. Choong Ho Choi

The Graduate School

Yonsei University

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ABSTRACT

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Directed by Professor Baek Il Kim

Department of Dentistry, The Graduate School of Yonsei University

Hye Young Oh

Dental hygiene assessment of tooth lesions, restorations, and periodontal conditions has been performed by visual inspection, a conventional assessment method. However, distinguishing tooth lesions, restorations, periodontal conditions, and dental plaque with visual inspection alone is a great challenge for dental hygiene students without much experience.

As an assessment tool, the recently developed Quantitative Light-induced Fluorescence-digital Biluminator™ (Q-Ray™ system) can not only detect tooth lesions such as incipient caries and dental caries, but also distinguish natural tooth-like porcelain or ceramic crowns and detect and quantify red autofluorescent dental plaque emitted by the endogenous porphyrins generated by intraoral bacteria.

Therefore, integrating such a reliable diagnostic tool in theoretical education and practical training of dental hygiene students would greatly enhance students' diagnostic accuracy and assessment performances.

This study was conducted with approval from the Institutional Review Board of the Yonsei University Dental Hospital (IRB No: 2-2014-0023). In this study, a performance comparison in the assessment of tooth lesions, restorations, and periodontal conditions was performed between visual inspection alone and visual inspection assisted by the Q-Ray^{TM} system. The assessment results of both methods were checked against the gold standard in order to compare their assessment accuracy and check whether different results had been yielded by the two methods.

The subject population of this study was 110 dental hygiene students, of whom 92 and 18 students were enrolled as assessors and simulated patients, respectively. The 92 assessors were randomly assigned to the experimental or control group, 46 each, and the 18 simulated patients were assigned to the experimental or control group, 9 each, with attention paid to equitable distribution of lesions and restorations.

Based on the assessment results of the experimental and control groups, Cohen's kappa values were calculated for each group, whereupon each group was subdivided into upper (30%), middle (40%), and lower (30%) grade subgroups. The tooth lesions, restorations, and periodontal conditions were then compared for each subgroup using kappa values and percent agreements.

In the intergroup comparison of the assessment accuracy for tooth lesions, a significant difference was found only in the image test results of the middle grade subgroups, whereby the experimental group showed a higher percent agreement than the control group (64% vs. 62%; $p = 0.043$).

In the assessment of restoration, the experimental group students of all three grades outperformed their control group counterparts in terms of kappa values and percent agreements in both the image and simulated patient tests, thus demonstrating that the application of the Q-Ray^{TM} system enhances the detection accuracy.

By type of restoration, the experimental group using the Q-Ray^{TM} system showed higher percent agreements in the image test with 62.6% for composite resin ($p = 0.006$) and 78.3% for porcelain crown ($p < 0.001$) than the control group with 56.0% and 52.9%, respectively. Also, the percent agreements of the experimental group in the simulated patient test was higher with 66.0% than the control group with 42.9% for composite resin ($p < 0.001$).

The comparison of the performance in discriminating periodontal conditions by grade revealed that middle and lower grade students in the experimental group showed higher kappa values and percent agreements in both the image and simulated student tests compared to their counterparts in the control group. This means that the use of the Q-Ray^{TM} system enhanced the performance of middle and lower grade students in detecting periodontal anomalies and dental plaque, while higher grade students' performance was less influenced by the use of the Q-Ray^{TM} system.

The results of this study allow the conclusion that the use of the Q-Ray^{TM} system as an aid in distinguishing dental and periodontal conditions in dental hygiene assessment can be expected to contribute to improving the assessment accuracy in dental hygiene process of care and enhancing students' assessment performance.

Keywords: Dental hygiene assessment, Dental hygiene process of care, Simulated patient, Quantitative light-induced fluorescence-Digital

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Hye Young Oh

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(Directed by Professor Baek-Il Kim)

I. INTRODUCTION

Dental hygiene process of care is a systematic process that dental hygienists go through to satisfy clients' demands related to oral health; it consists of five components of dental hygiene assessment, dental hygiene diagnosis, planning, implementation, and evaluation (Darby and Walsh, 2015). Dental hygiene assessment, the first component of the dental hygiene process of care, is a stage where the basic dental information, oral disease, or related risk factors, and clinical features of a client are systematically assessed in order to determine the client's unmet need. The assessment of clinical features includes intra- and extra-oral examination, identification of periodontal conditions, such as periodontal parameter, presence, degree and distribution of plaque and calculus, gingival health and diseases, and comprehensive assessment of dental hard tissues, such as

demineralization, caries, defects, sealants, existing restoration and potential needs, anomalies, occlusion, fixed and removable prostheses, and missing teeth. As methods of assessment, along with conventional methods of visual–tactile examination and radiography, a variety of diagnostic devices and tools are in use (American Dental Hygienists' Association, 2008).

Dental hygiene assessment is the first stage of the process of finding out clients' unmet need in order to attend to them, which is the core objective of the dental hygiene process of care. An accurate assessment is the basis for the rest of the process, and the assessment of the general oral health status of each client, such as tooth lesions, caries or cervical abrasion, restorations, and periodontal conditions, is essential for dental hygiene care planning and implementation (Walsh and Darby, 1993; Fitch, 2004).

Therefore, it is of vital importance to train dental hygiene students to acquire the ability to make an exact assessment of tooth lesions, restorations, and dental calculus or dental plaque, which are basic elements of periodontal conditions. For this, simulation has been introduced as a pivotal training model in dentistry along with medical and nursing education; it is a proven method for improving students' performance in clinical settings (Buchanan, 2001; Meyer et al., 2011). Additionally, it provides students with hands-on opportunities to handle a variety of clinical situations, has excellent repeatability and reproducibility, and enhances the accuracy of assessment (Foster, 2008). However, most simulation-based education programs are concerned with performance test and treatment procedure (Issenberg et al., 1999; Kramer et al., 2002; Hawley et al., 2009), and thus provide only limited simulation situations for assessing intraoral lesions or restorations. Even in clinical practice with simulated or real patients, dental examinations are performed in conventional methods such as visual inspection or tactile

palpation and radiographic images (Swanson, 1999).

With such conventional methods alone, however, even specialists with excellent clinical skills cannot be fully relied on for detection accuracy (Weerheijm et al., 1989; Wenzel et al., 1991) and a supplementary use of reliable diagnostic tools is advisable to enhance the accuracy of assessment (Lizarelli, 2004). For this reason, a variety of diagnostic devices, such as DIAGNOdent and QLF, have been developed, and have found broad applications in parallel with conventional assessment methods (Shi et al., 2001; Lizarelli et al., 2004; Mestriner et al., 2005). Also in the dental hygiene process of care, there are ongoing discussions about using reliable diagnostic tools, such as DIAGNOdent, DIFOIT, or QLF recently developed, but their actual application rate is still very low (Stookey, 2003; Barnes, 2005).

Optical equipment can detect intraoral disorders using light sources of a variety of wavelengths; in fact, incipient caries with reduced mineral content could be detected in the visible blue light spectrum (Bjelkhagen and Sundström, 1981). Quantitative Light-induced Fluorescence (QLF; Inspektor, model QLF 1.0) was initially developed as a device to detect incipient caries difficult to be detected by visual-tactile examination (de Josselin et al., 1995). The Quantitative Light-induced Fluorescence-Digital Biluminator™ (Q-Ray™) device with a special filter mounted to the digital camera was evolved from QLF to enable it to detect red autofluorescent dental plaque emitted by endogenous porphyrins generated by bacteria (Hope et al., 2011; van der Veen et al., 2006). Both white and blue images can be obtained with one shot without staining, which enables the detection of dental calculus and dental plaque, as well as incipient caries, without any extra staining (Alammari et al., 2013; Kim et al., 2013; Kim et al., 2014).

The Q-Ray™ system includes QLF-D, which allows quantitative analysis of incipient caries or microbial films (dental plaque) formed on tooth surfaces, and Q-Ray view, a handy version that can be used conveniently anywhere by anybody regardless of imaging conditions without quantitative analysis. So the Q-Ray™ system can be used by dental hygiene students to enhance their assessment performance by improving assessment accuracy. The purpose of present study was to determine the effects of the Q-Ray™ system on the improvement of assessment accuracy and dental hygiene students' assessment performance when used for the dental hygiene assessment in the first practical training of dental hygiene process of care and to establish an efficient application modality of the Q-Ray™ system for the dental hygiene process of care.

In summary, the purpose of this study was as follows: (a) to determine whether the assessment accuracy increases when students use the Q-Ray™ system in assessing tooth lesions, restorations, and periodontal conditions; (b) to evaluate the differences in assessment accuracy, if any, between the experimental group that used the Q-Ray™ system and the control group that did not use the Q-Ray™ system by performance category, by subdividing each group into upper, middle, and lower grade subgroups.

II. MATERIALS AND METHODS

2.1. Study design

This study was conducted with the approval of the Institutional Review Board of Yonsei University College of Dentistry Hospital (IRB No.: 2-2014-0023). For experimental purposes, 18 simulated patients with at least two tooth lesions and restorations were enrolled and 92 dental hygiene students were enrolled as dental hygienists to directly perform the dental hygiene assessment. The 92 student assessors were randomly assigned to the experimental group that uses both visual assessment and the Q-Ray™ system or to the control group that uses only visual assessment, 46 each. The 18 simulated patients were assigned to each group, 9 each, by the researcher, with attention paid to an even distribution of lesions and restorations.

Prior to the experiment, preliminary training was performed using QLF-D captured images, and the students familiarized themselves with the use of the Q-Ray view, which is used for the simulated patient evaluation, through mutual training.

Upon completion of the prior training, a brief test was performed to check whether the students mastered the required skills. Then the image test was administered using the QLF-D captured images, followed by the simulated patient test using the Q-Ray view.

Assessment results were checked against the gold standard provided by the reference assessor, and the assessment performances were compared between the experimental and control groups with their respective kappa values and percent agreements thus obtained (Figure 1).

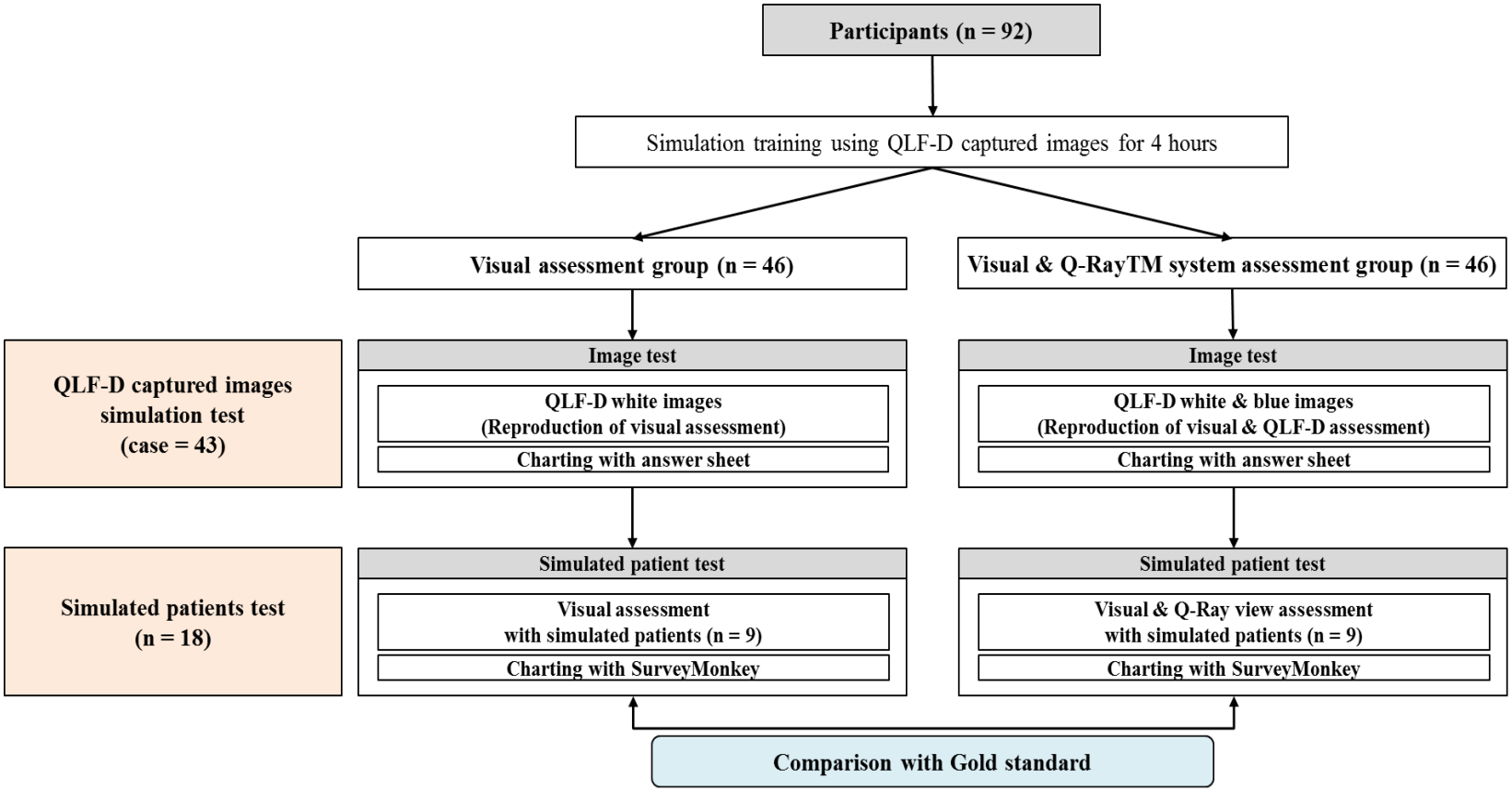

Figure 1. Diagram of study design

2.2. Subject population

The subject population was 110 dental hygiene students who were enrolled according to the inclusion and exclusion criteria and agreed to participate in the study by signing the informed consent form. Of these 110 subjects, 92 and 18 assumed the roles of assessors and simulated patients, respectively.

The 92 assessors were randomly assigned by lot to the experimental or control group, 46 each.

As simulated patients, 18 subjects were selected by screening 74 volunteers who were recruited through a prior announcement. Two experienced dentists performed the screening according to the selection criterion of two or more tooth lesions or restorations and selected 18 students. The researcher assigned these 18 simulated patients to the experimental or control group, 9 each, in a manner that ensures an even distribution of lesions and restoration.

2.3. Study procedures

2.3.1. Quantitative Light induced Fluorescence-Digital Biluminator ™ (Q-Ray™)

The Q-Ray™ (Inspektor Research systems BV, Amsterdam, The Netherlands) was designed to obtain normal white light and blue light images at the same time with one shot by mounting a light-emitting diode composed of 4 white light and 12 blue light, which wavelength is 405-nm, sources to the digital camera. QLF-D can enhance a higher degree of accuracy by detecting the small changes that tooth surfaces with caries and loss of mineral contents appear darker than the sound tooth surfaces (Stookey, 2005; Alammari et al., 2013), and by detecting the red auto-fluorescence emitted by the endogenous porphyrins generated by bacteria in intraoral sites without the need of staining them (Coulthwaite et al., 2006) (Figure 2a). The Q-Ray view, simple version of Q-Ray^{TM} system, is a portable handy device that allows easy detection of dental plaque on teeth surfaces and caries lesions using a goggle with an embedded special filter. It is thus expected to be efficiently used under any clinical settings (Figure 2b).

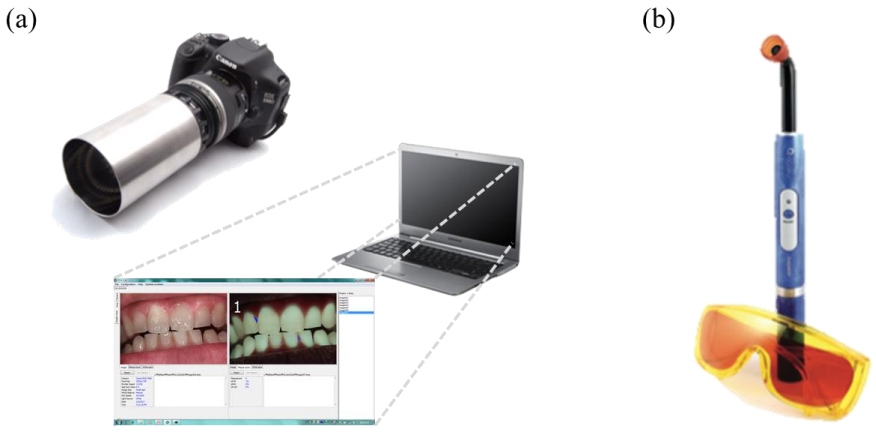

Figure 2. Quantitative Light-induced Fluorescence System devices;

(a) QLF-D and (b) Q-Ray view

2.3.2. Selection of assistants and assessment charting

For the implementation of assessment data input, 18 higher-grade dental hygiene students, matching the number of the simulated patients, were recruited by personal contact. They were given sufficient explanations and instructions regarding the study progress protocol (filling in the chart, monitoring the lights, adjusting the chair height, ensuring simulated patients' comfort, and passing on or receiving safety glasses and other apparatuses in case of using the Q-Ray view). They were requested to strictly refrain from any influencing gestures (advice or hindrance) while the students were performing the dental hygiene assessment.

The assistants were instructed to enter the results of the image test by marking "v" in the answer sheet prepared.

The results of the simulated patient test were coded in the order of tooth lesions, restorations, and periodontal conditions and inputted into the checkbox using the online survey tool, SurveyMonkey. The link to the correspondingly customized chart was transmitted to the 18 assistants via KakaoTalk (Korea-based messenger service) so that the assessment results can be immediately inputted into the online survey server via smartphone. The answers could be directly inputted into the SurveyMonkey server and utilized for analysis without extra decoding (Figure 3 and 4).

Figure 3. A capture of SurveyMonkey chart

Figure 4. Charting using SurveyMonkey

2.3.3. Q-Ray™ system training

The 92 student assessors were given prior training to make them familiar with the principle and handling of the Q-Ray™ system. They were then given simulation training, in which two images are repeatedly displayed from the white and blue images of the QLF-D-captured images, so that they can distinguish tooth lesions, restorations, dental plaque, and dental calculus.

Upon completion of the training, the trainees went through a brief test checking whether they understood the training content. The training consisted of theory part, mutual practice part, and test part, with a total duration of 4 hours.

2.3.4. Image test

Upon completion of the training, the image test was administered. Based on the white and blue images of the QLF-D captured images, a total of 43 case slides were generated, with an even distribution of tooth lesions, restorations, and dental plaque and calculus. Assessment was performed in two separate multimedia-enabled lecture rooms (e.g., with PCs, beam projectors, and large monitors) for the experimental and control groups monitored by a facilitator for each group.

The 46 students assigned to the control group were shown only white images reproducing the visual inspection of the intraoral environment, and the 46 patients assigned to the experimental group were shown the slides displaying both white and blue images of the same images by reproducing the environment that allows the visual inspection of the Q-Ray view at the same time.

The prepared slides were shown to the students of both groups at an interval of 30 s per slide, and the students were instructed to input their answers after assessing the captured images by marking the corresponding checkboxes on the prepared answer sheet with “v”.

The gold standard for each slide used for the image test was established in advance by two experienced and skilled dentists, whereby the parts displaying inter-assessor discrepancy were adjusted by mutual consensus. The assessment outputs of the experimental and control groups were checked against the gold standard of the reference assessors (Figure 5).

Figure 5. A picture showing assessment progress using QLF-D images

2.3.5. Simulated patient test

The simulated patient test was administered to the same experimental and control groups that went through the image test. The 18 simulated patients recruited in advance were assigned to each group at the same ratio in the number of patients and the distribution of tooth lesions and restorations. Five or six students performed assessment on one simulated patient. The Q-Ray™ system used for visual assessment by the experimental group was a handy model of Q-Ray view, and the control group performed visual assessment without using the Q-Ray view. Oral conditions were arranged to be the same as in the image test, dividing them into tooth lesions, restorations, and periodontal conditions (Figure 6).

At the end of the test session, each simulated patient was assessed by a skilled dentist to establish a gold standard. The assessment results were charted into a separate record sheet by an assistant. Simulated patients who went through the test session and final assessment were subjected to intraoral image capturing with QLF-D on the labial, buccal, and occlusal surfaces, and the resulting white and blue images were stored in a PC as bitmap files (Figure 7).

The gold standard for each simulated patient was established by two dentists on the basis of the dentist's assessment result and the QLF-D image. The assessment results of the 92 student assessors were checked against the gold standards of the reference assessors.

Figure 6. A picture showing assessment progress with simulated patients

Figure 7. A picture of QLF-D image taking for the gold standard

2.3.6. Assessment items

The assessment items for both image test and simulated patient test were teeth lesions, restorations, and periodontal conditions. Tooth lesions included dental caries, including incipient caries and cervical abrasion. Restorations included amalgam, resin or resin inlay, ceramic inlay, porcelain or ceramic crown, gold inlay, and gold crown. Periodontal conditions assessed were dental plaque and dental calculus that are associated with periodontal diseases (Figure 8 and 9).

2.3.7. Assessment methods

Both experimental and control groups were asked to mark any tooth lesion found to be present without regard to its location. The same applied to restorations.

Dental plaque or calculus was considered to be present when the Q-Ray view detected the emission of red autofluorescence. For the control group, only plaques with score 1 or higher on the Löe and Silness' plaque index were taken into consideration (Löe, 1967).

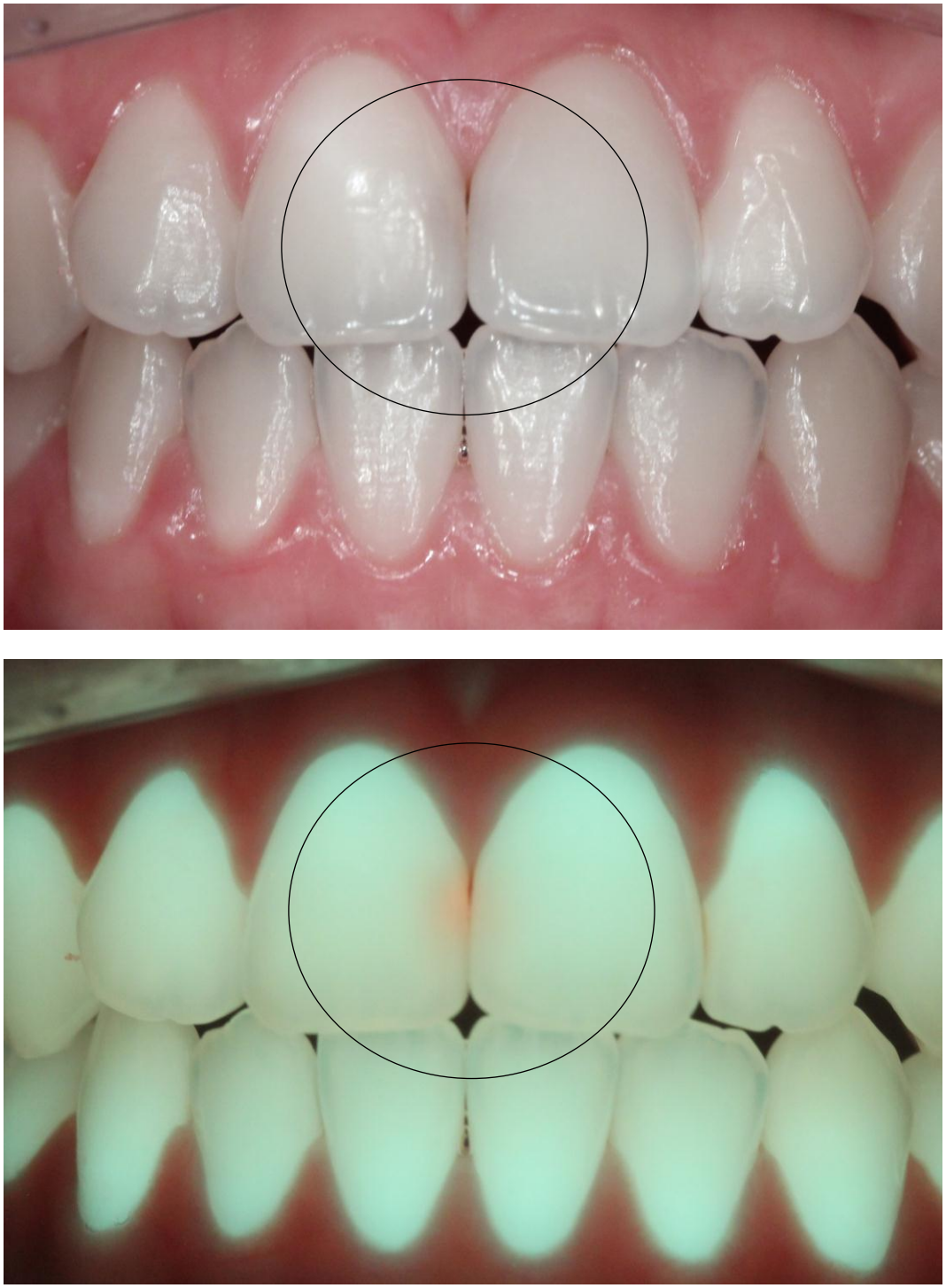

Figure 8. QLF-D Image of incipient caries under white (above) and blue light (below)

Figure 9. QLF-D Image of porcelain crown and dental plaque under white (above) and blue light (below)

2.4. Statistical analysis

All 92 subjects in the experimental and control groups were subdivided into three performance groups of upper 30%, middle 40%, and lower 30% of each group by obtaining the Cohen's kappa value of each student and comparing the values. The assessment results on tooth lesions, restorations, and periodontal conditions were then analyzed and compared between the experimental and control groups by grade.

The subjects' assessment results and those of the reference assessors were compared to obtain the percent agreement of each result for each of the three assessment items of tooth lesions, restorations, and periodontal conditions.

An independent sample t-test was performed to compare the Cohen's kappa values between the experimental and control groups. The percent agreements of each item were compared using the Pearson chi-square test for two proportions.

All statistical analysis was performed using the statistical package SPSS Statistics 21.0 program (SPSS Inc., Chicago, USA), and the level of significance was set at 0.05.

III. RESULTS

3.1. Image test

3.1.1. Students' assessment accuracy by grade

3.1.1.1. Comparison of kappa values for tooth lesions by grade

The control and the experimental groups obtained similar overall mean kappa values approximating 0.42 ($p = 0.973$). The mean kappa values of the upper 30% subgroups of the experimental and control groups were 0.63 and 0.62 ($p = 0.943$), respectively, the middle 40% subgroups, 0.41 and 0.42 ($p = 0.440$), and the lower 30% subgroups, 0.24 and 0.22 ($p = 0.666$), without showing any statistically significant intergroup differences (Table 1) (Figure 10).

Table 1. Mean kappa values for lesion by grade

Lesion	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.6272	0.1177	0.6243	0.0958	0.943
Middle 40%	36	0.4062	0.0354	0.4181	0.0541	0.440
Lower 30%	28	0.2380	0.1137	0.2215	0.0844	0.666
Total	92	0.4223	0.1788	0.4210	0.1762	0.973

S.D.: Standard deviation
*p-values calculated using independent sample t-test

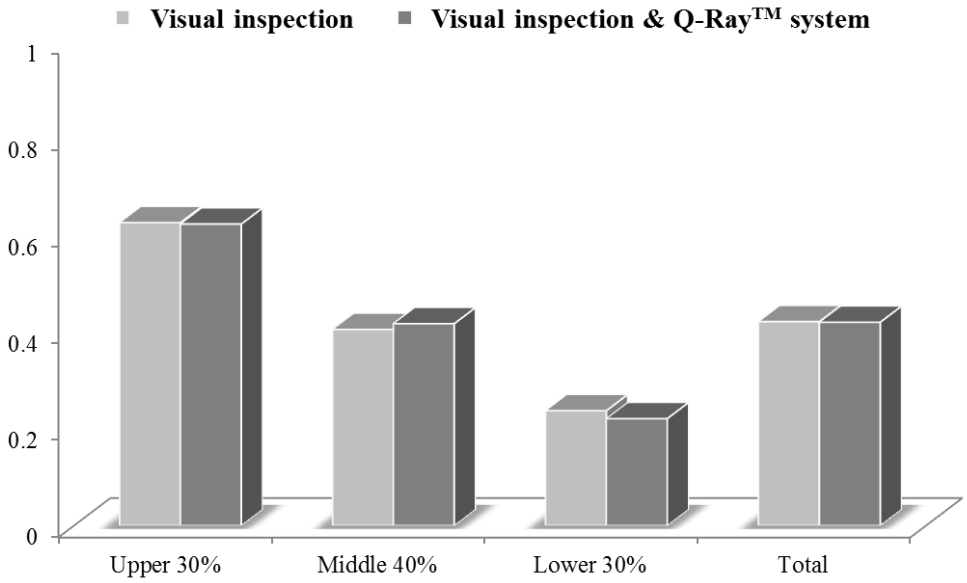

Figure 10. Comparison of kappa values between two methods for tooth lesions by grade

3.1.1.2. Comparison of percent agreements for lesions by grade

Table 2 outlines the results of calculating the percent agreements for lesions by grade. The mean percent agreements of the control and experimental groups (n = 92) were 62.8% and 64.8%, respectively (p = 0.379). The average percent agreement of the upper 30% subgroup (n = 14 for each group) was 75.6% for the control group and 76.8% for the experimental group (p = 0.624). The same for the middle 40% subgroup (n = 18 for each group) was significantly higher in the experimental group compared to the control group (64.1% vs. 62.1%; p = 0.043). The average percent agreement of the lower 30% subgroup (n = 14 for each group) was 51.1% for the control group and 53.7% for the experimental group (p = 0.221) (Figure 11).

Table 2. Mean percent agreement for lesion by grade

Lesion	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.7561	0.0735	0.7683	0.0556	0.624
Middle 40%	36	0.6206	0.0267	0.6409	0.0311	0.043
Lower 30%	28	0.5105	0.0631	0.5366	0.0459	0.221
Total	92	0.6283	0.1114	0.6479	0.1012	0.379

S.D.: Standard deviation
*p-values calculated using independent sample t-test

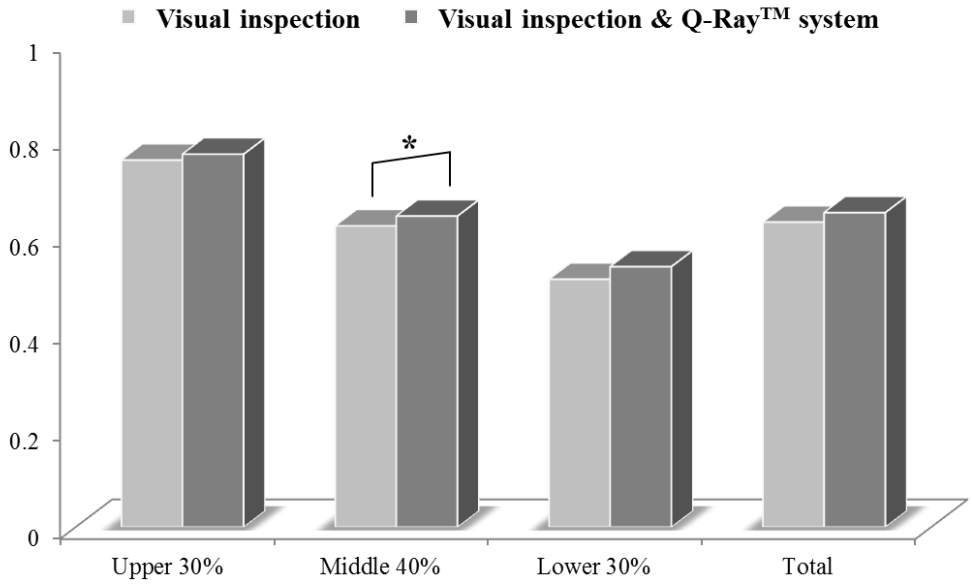

Figure 11. Comparison of mean percent agreements between two methods for tooth lesions by grade

3.1.1.3. Comparison of kappa values for restorations by grade

The overall mean kappa value for restorations was 0.60 for the control group and 0.70 for the experimental group, with the experimental group demonstrating significantly higher assessment accuracy ($p = 0.001$). Comparison by grade revealed that the experimental group showed higher in all grades, with the mean kappa values of the upper 30% subgroups of control and experimental groups being 0.77 and 0.85 ($p = 0.003$); the same for the middle 40% were 0.60 and 0.71 ($p < 0.001$) and the lower 30%, 0.42 and 0.54 ($p = 0.009$). In all three subgroups, the experimental group using the Q-Ray™ system outperformed the control group that did not use the Q-Ray™ system, thereby showing an assessment accuracy closer to the reference assessors when both white and blue images existed on the QLF-D images (Table 3) (Figure 12).

Table 3. Mean kappa values for restoration by grade

Restoration	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.7729	0.0734	0.8456	0.0378	0.003
Middle 40%	36	0.5983	0.0530	0.7145	0.0404	<0.001
Lower 30%	28	0.4226	0.0900	0.5375	0.1225	0.009
Total	92	0.5980	0.1551	0.7005	0.1423	0.001

S.D.: Standard deviation
*p-values calculated using independent sample t-test

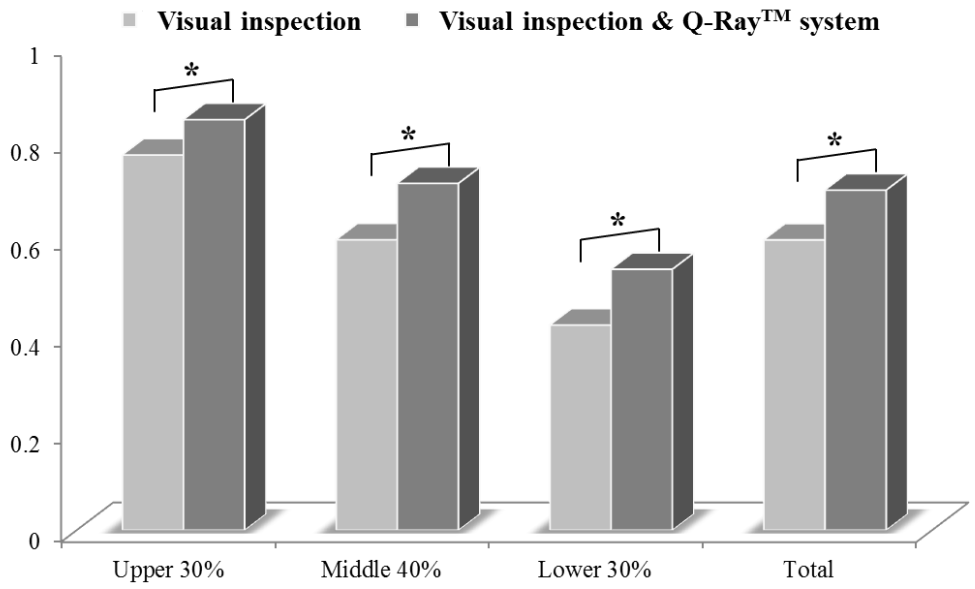

Figure 12. Comparison of kappa values between two methods for restorations by grade

3.1.1.4. Comparison of percent agreements for restorations by grade

The mean percent agreements of the upper 30% subgroups of the control and experimental group were 84.7% and 89.7% ($p = 0.002$), the middle 40%, 72.6% and 80.9% ($p < 0.001$), and the lower 30%, 60.6% and 69.3% ($p < 0.001$). In each of the three subgroups, the experimental group showed significantly higher assessment accuracy with the gold standard. The overall mean percent agreements for the control and experimental groups were 72.6% and 80.1%, respectively ($p < 0.001$) (Table 4) (Figure 13).

Table 4. Mean percent agreement for restoration by grade

Restoration	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.8467	0.0501	0.8972	0.0256	0.002
Middle 40%	36	0.7263	0.0341	0.8090	0.0293	<0.001
Lower 30%	28	0.6063	0.0415	0.6934	0.0727	<0.001
Total	92	0.7264	0.1032	0.8006	0.0925	<0.001

S.D.: Standard deviation
*p-values calculated using independent sample t-test

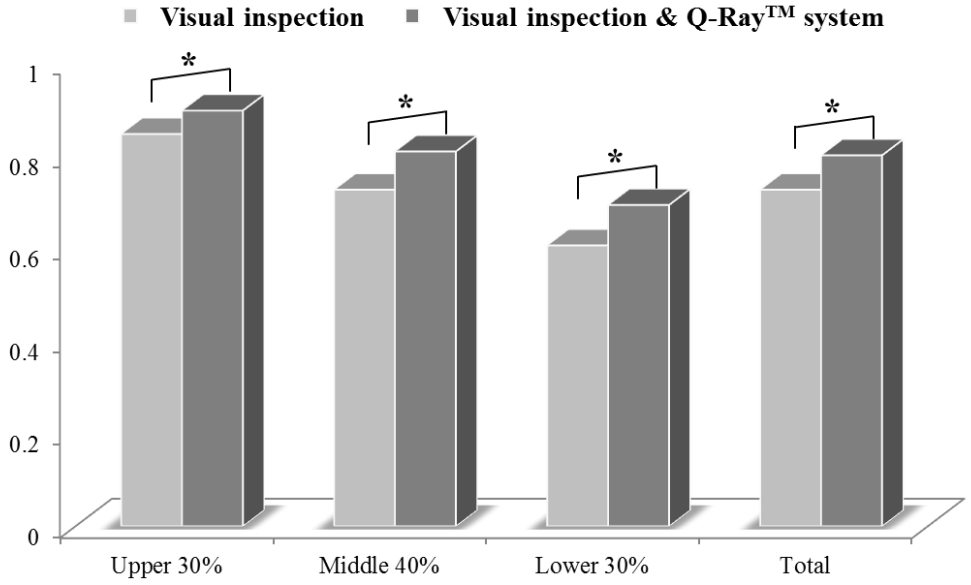

Figure 13. Comparison of mean percent agreements between two methods for restorations by grade

3.1.1.5. Comparison of mean kappa values for periodontal conditions by grade

The overall degrees of agreement for the control and experimental groups were 0.18 and 0.29, with a statistically significant difference in favor of the experimental group ($p = 0.008$). The upper 30% subgroups did not show a statistically significant difference with 0.41 and 0.43 ($p = 0.876$). The middle 40% and lower 30% subgroups scored very low in mean kappa values with 0.13 and 0.29 ($p < 0.001$) and 0.02 and 0.16 ($p < 0.001$), respectively, but the intergroup differences were statistically significant (Table 5) (Figure 14).

Table 5. Mean kappa values for periodontal condition by grade

Periodontal condition	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.4083	0.2666	0.4208	0.1279	0.876
Middle 40%	36	0.1319	0.0870	0.2875	0.0866	<0.001
Lower 30%	28	0.0178	0.0525	0.1549	0.0899	<0.001
Total	92	0.1813	0.2226	0.2877	0.1446	0.008

S.D.: Standard deviation
*p-values calculated using independent sample t-test

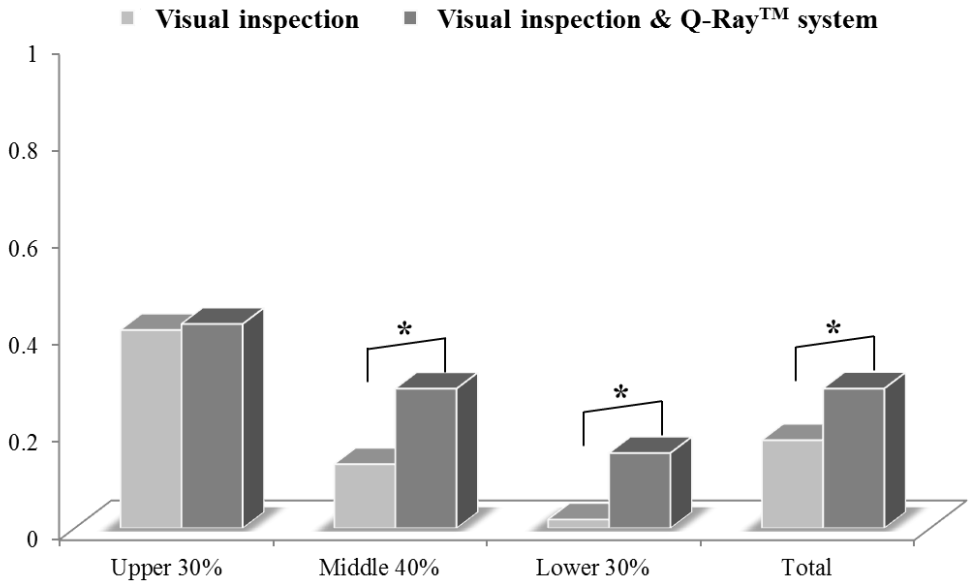

Figure 14. Comparison of kappa values between two methods for periodontal conditions by grade

3.1.1.6. Comparison of percent agreements for periodontal conditions by grade

The control and experimental groups showed a statistically significant difference in the mean percent agreements for periodontal conditions with 56.8% and 64.5% ($p < 0.001$). The upper 30% subgroups did not show a statistically significant difference with 70.2% and 71.6% ($p = 0.677$). The mean percent agreements of the middle 40% subgroups of the control and experimental groups were 54.7% and 64.5%, with the experimental group showing higher assessment accuracy ($p < 0.001$). The same for the lower 30% subgroups were 46.2% and 57.5% ($p < 0.001$), with the experimental group showing higher assessment accuracy (Table 6) (Figure 15).

Table 6. Mean percent agreement for periodontal condition by grade

Periodontal condition	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.7021	0.1120	0.7160	0.0521	0.677
Middle 40%	36	0.5474	0.0254	0.6450	0.0225	<0.001
Lower 30%	28	0.4617	0.0411	0.5749	0.0354	<0.001
Total	92	0.5684	0.1168	0.6453	0.0666	<0.001

S.D.: Standard deviation
*p-values calculated using independent sample t-test

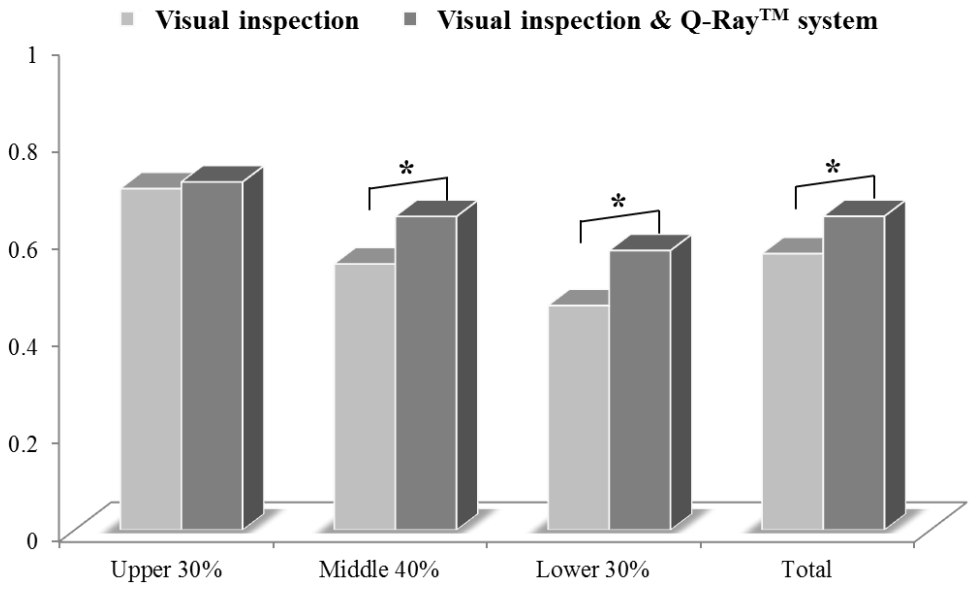

Figure 15. Comparison of mean percent agreements between two methods for periodontal conditions by grade

3.1.2. Assessment accuracy by item

3.1.2.1. Comparison of percent agreements by type of lesion

A total of 3772 teeth were assessed to have lesions. Of these, 1840 were sound teeth, and the experimental group, which used the Q-Ray™, showed higher assessment accuracy than the control group, which did not use it (83.5% vs. 71.6%; $p < 0.001$). The total number of teeth assessed to have incipient caries was 368, and the percent agreements of the control and experimental groups were 39.1% and 23.9% ($p < 0.001$), with the control group showing a significantly higher degree of agreement. A total of 1288 teeth were classified as caries, and the control group outscored the experimental group with 57.3% vs. 46.9% ($p < 0.001$), showing a mean percent agreement closer to the gold standard. The two groups yielded the same score in cervical abrasion, and thus the p-value could not be calculated (Table 7) (Figure 16).

Table 7. Percent agreement for tooth status by type of lesion

Lesion	N	Visual inspection	Visual inspection & Q-Ray™ system	P-values*
Sound	1840	71.63%	85.87%	<0.001
Incipient caries	368	39.13%	23.91%	<0.001
Caries	1288	57.30%	46.89%	<0.001
Cervical abrasion†	276	62.32%	62.32%	
Total	3772			

*p-values calculated using two-sample test of proportions.
†No differences were observed and two-sample tests for proportions were not performed.

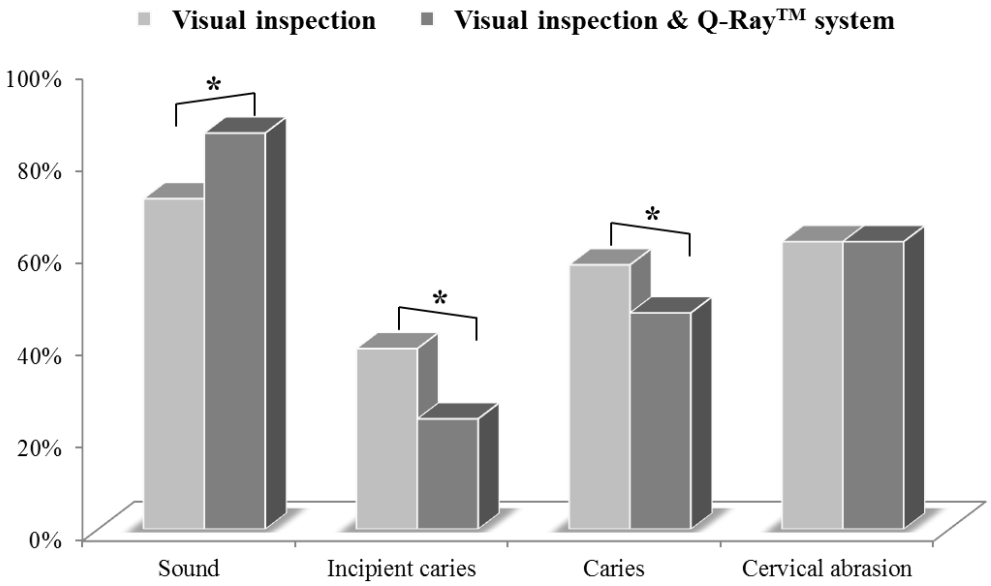

Figure 16. Comparison of percent agreements between two methods for tooth status by type of lesion

3.1.2.2. Comparison of percent agreements by type of restoration

Of the 3772 teeth assessed to be restorations, 2024 were sound teeth, and the experimental group outscored the control group with 83.4% vs. 75.3% ($p < 0.001$). The number of amalgams was 184, and the percent agreements of the control and experimental groups were 91.3% and 92.4%, showing no statistically significant difference ($p = 0.703$). The number of teeth assessed to be composite resin was 828, and the percent agreements of the control and experimental groups were 56.0% and 62.6%, with the experimental group showing a higher mean percent agreement ($p = 0.032$). There were 276 porcelain crowns, and the experimental group outperformed the control group (78.3% vs. 53.0%) with statistical significance ($p < 0.001$) when both white and blue light sources were on the QLF-D images. A total of 184 teeth were assessed to have gold inlay, and the mean percent agreements of the control and experimental groups were 96.7% and 93.5%, both groups showing a high assessment accuracy with no statistically significant intergroup difference ($p = 0.155$). There were 276 gold crowns, and with 94.2% and 92.8% ($p = 0.505$), both control and experimental groups showed high assessment accuracy with the answers provided by the reference assessors (Table 8) (Figure 17).

Table 8. Percent agreement for tooth status by type of restoration

Restoration	N	Visual inspection	Visual inspection & Q-Ray™ system	P-values*
Sound	2024	75.30%	83.40%	<0.001
Amalgam	184	91.30%	92.39%	0.700
Composite	828	56.04%	62.56%	0.006
Gold inlay	184	96.74%	93.48%	0.155
Gold crown	276	94.20%	92.75%	0.505
Porcelain crown	276	52.90%	78.26%	<0.001
Total	3772			

*p-values calculated using two-sample test of proportions.

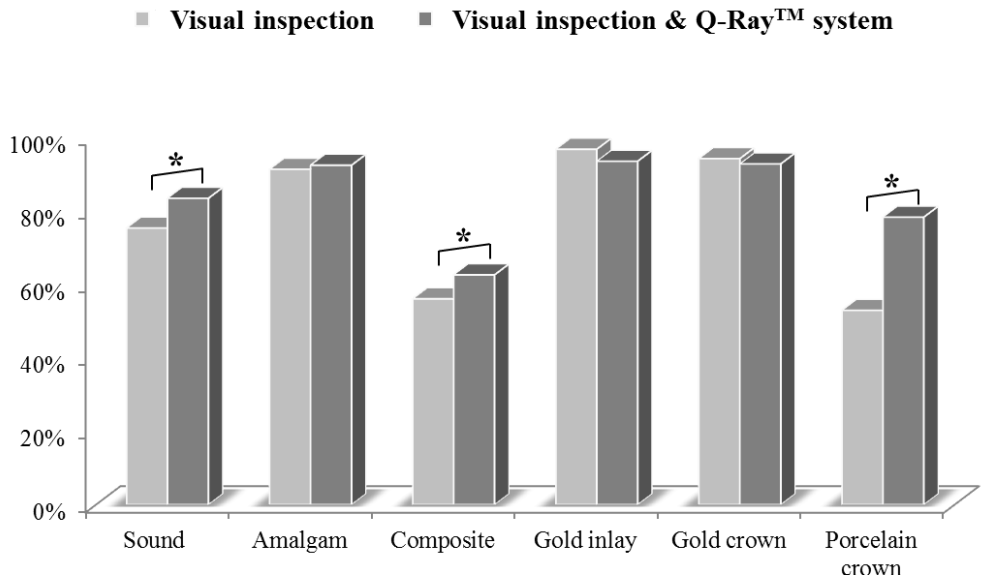

Figure 17. Compared percent agreement for tooth status by type of restoration

3.1.2.3. Comparison of percent agreements by type of periodontal condition

A total of 3772 teeth were assessed to have periodontal conditions. Of these, 2300 were sound teeth, and the control group, which used only white light on QLF-D images, scored 72.7%, and the experimental group, which used both white and blue images on the QLF-D images, scored 81.3% ($p < 0.001$).

A total of 1288 teeth were detected to have dental plaque, and the percent agreements of the control and experimental groups were 24.8% and 33.9%, thus demonstrating that higher assessment accuracy could be achieved in the presence of both white and blue images ($p < 0.001$).

A total of 184 dental calculus sites were spotted, and the control group outscored the experimental group with 82.6% vs. 69.6% agreements ($p = 0.003$) (Table 9) (Figure 18).

Table 9. Percent agreement for tooth status by type of periodontal condition

Periodontal condition	N	Visual inspection	Visual inspection & Q-Ray™ system	P-values*
Sound	2300	72.70%	81.30%	<0.001
Plaque	1288	24.84%	33.85%	<0.001
Calculus	184	82.61%	69.57%	0.003
Total	3772			

*p-values calculated using two-sample test of proportions.

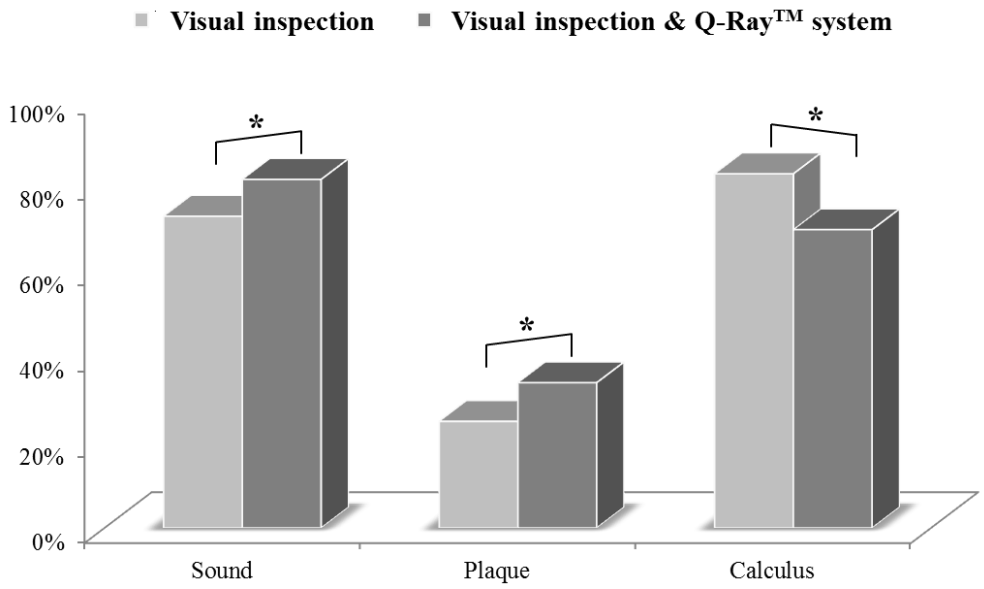

Figure 18. Compared percent agreement for tooth status by type of periodontal condition

3.2. Simulated patient test

3.2.1. Students' assessment accuracy by grade

3.2.1.1. Comparison of kappa values for tooth lesions by grade

No difference was observed in kappa values between the control and experimental groups. The overall mean kappa values were 0.13 for the control group and 0.15 for the experimental group ($p = 0.708$). The mean kappa values of the upper 30% subgroups of the control and experimental groups were 0.35 and 0.44 ($p = 0.222$) and the middle 40% subgroups, 0.09 and 0.07 ($p = 0.440$). With the lower 30% subgroups marking –0.02 and –0.01 ($p = 0.399$), the middle and lower grade students of both groups showed very low kappa values in comparison with the upper grade students (Table 10) (Figure 19).

Table 10. Mean kappa values for lesion by grade

Lesion	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.3531	0.1116	0.4383	0.1814	0.222
Middle 40%	36	0.0891	0.0609	0.0659	0.0584	0.297
Lower 30%	28	-0.0192	0.0277	-0.0097	0.0206	0.399
Total	92	0.1336	0.1641	0.1507	0.2128	0.708

S.D.: Standard deviation
*p-values calculated using independent sample t-test

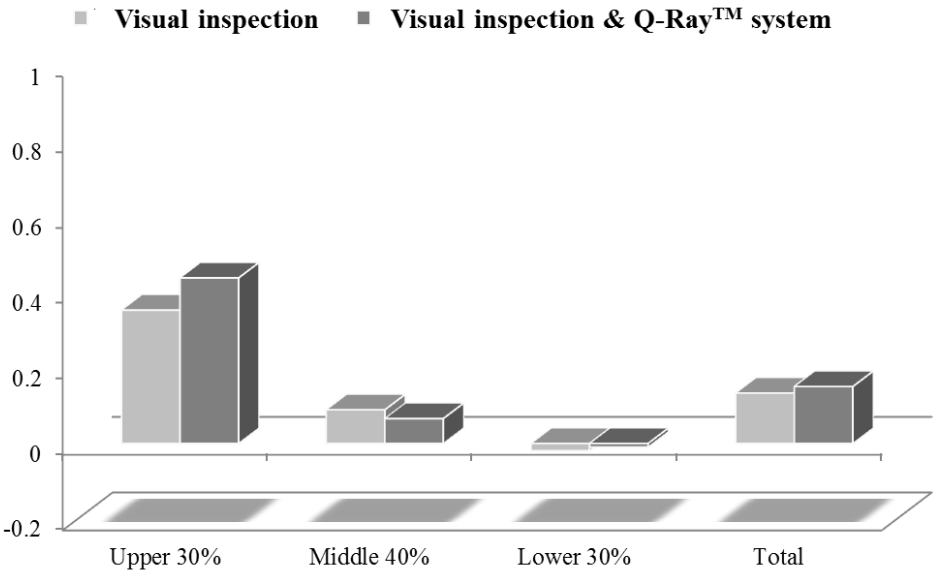

Figure 19. Compared mean kappa value for lesion by grade

3.2.1.2. Comparison of percent agreements for lesions by grade

The calculation of the students' mean percent agreements for lesions by grade resulted in the following findings: 76.1% for the upper 30% subgroups of both groups ($p = 1.000$). The same for the middle 40% subgroup was 58.8% for the control group and 56.0% for the experimental group, with the control group slightly outperforming the experimental group ($p = 0.623$). The lower 30% subgroup of the control group slightly outperformed their counterpart in the experimental group (69.3% vs. 63.9%; $p = 0.495$), but without statistical significance (Table 11) (Figure 20).

Table 11. Mean percent agreement for lesion by grade

Lesion	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.7607	0.0715	0.7607	0.1337	1.000
Middle 40%	36	0.5881	0.1932	0.5595	0.1102	0.623
Lower 30%	28	0.6929	0.2118	0.6393	0.1433	0.516
Total	92	0.6673	0.1847	0.6398	0.1494	0.495

S.D.: Standard deviation
*p-values calculated using independent sample t-test

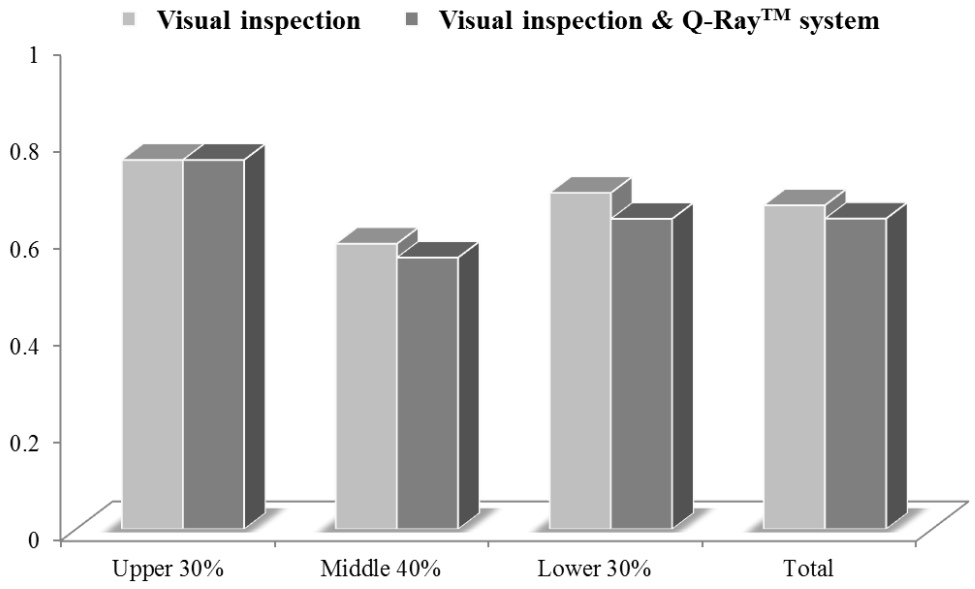

Figure 20. Compared mean percent agreement for lesion by grade

3.2.1.3. Comparison of kappa values for restorations by grade

The overall mean kappa value for restorations was 0.64 for the control group and 0.75 for the experimental group, with the experimental group slightly outperforming the control group, but without statistical significance ($p = 0.063$). The upper 30% subgroups of both control and experimental groups showed high mean kappa values of 0.95 and 1.00 ($p = 0.076$). The same for the middle 40% was 0.65 and 0.75, thus demonstrating that the use of Q-Ray view yielded a mean kappa value closer to the level of the reference assessors ($p = 0.008$). The lower 30% subgroups yielded 0.32 for the control group and 0.49 ($p < 0.001$) for the experimental group. Thus, the overall kappa values were higher for the experimental group (Table 12) (Figure 21).

Table 12. Mean kappa values for restoration by grade

Restoration	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.9519	0.0808	1.0000	0.0000	0.076
Middle 40%	36	0.6519	0.0789	0.7489	0.1044	0.008
Lower 30%	28	0.3160	0.1106	0.4948	0.0743	<0.001
Total	92	0.6417	0.2590	0.7480	0.2085	0.063

S.D.: Standard deviation
*p-values calculated using independent sample t-test

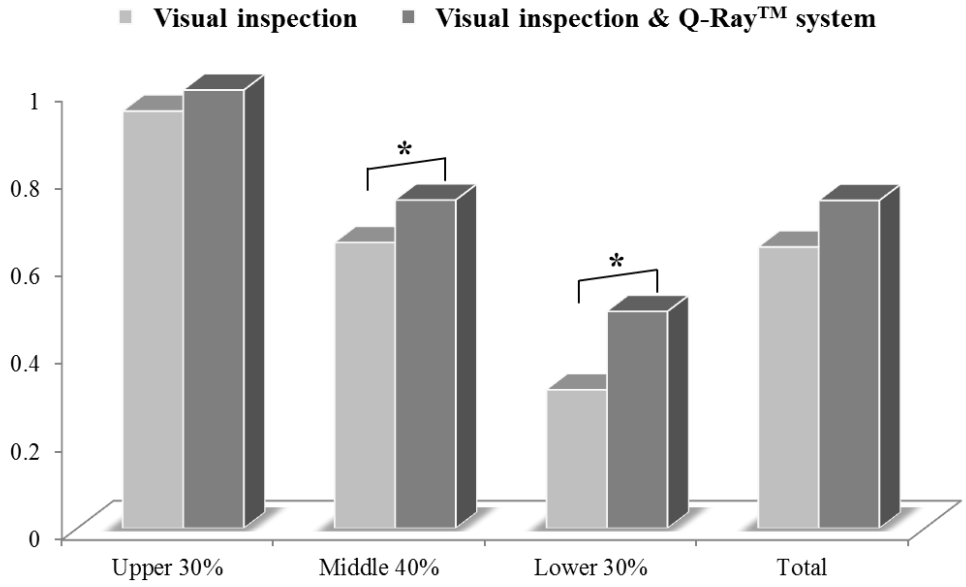

Figure 21. Compared mean kappa value for restoration by grade

3.2.1.4. Comparison of percent agreements for restorations by grade

The mean percent agreements of the upper 30% subgroups of the control and experimental group were 98.2% and 100.0%, with both subgroups demonstrating high assessment accuracy without statistically significant difference ($p = 0.079$). The middle 40% subgroups of the control and experimental group were 81.9% and 86.9%, with the experimental group showing significantly higher assessment accuracy ($p = 0.303$). Similar results were yielded by the lower 30% subgroups with 62.9% and 72.1% ($p = 0.053$). The overall mean percent agreements for the control and experimental groups were 81.1% and 86.4% ($p = 0.114$), but the differences did not reach statistical significance (Table 13) (Figure 22).

Table 13. Mean percent agreement for restoration by grade

Restoration	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.9822	0.0303	1.0000	0.0000	0.079
Middle 40%	36	0.8190	0.0564	0.8690	0.0628	0.030
Lower 30%	28	0.6286	0.1067	0.7214	0.0934	0.053
Total	92	0.8112	0.1517	0.8643	0.1240	0.114

S.D.: Standard deviation
*p-values calculated using independent sample t-test

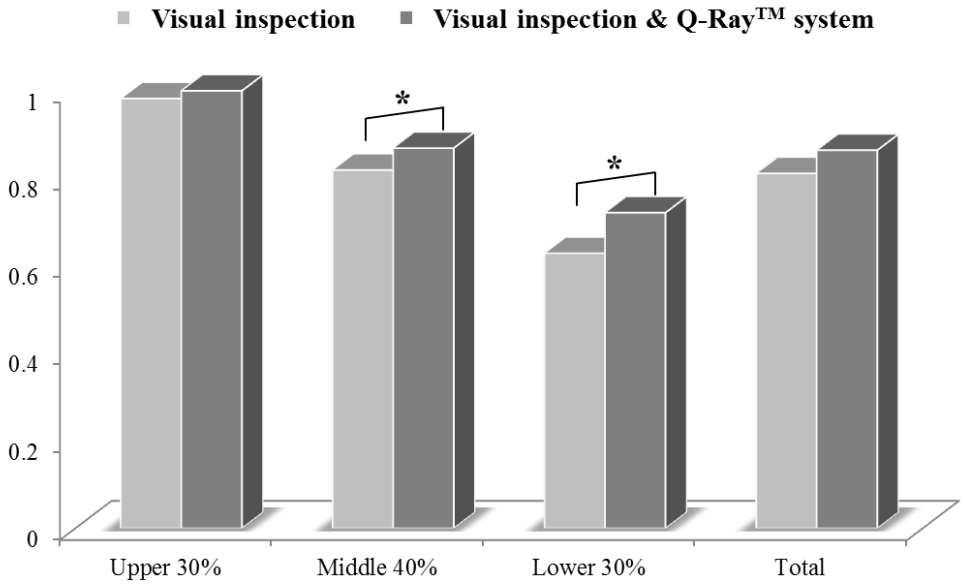

Figure 22. Compared mean percent agreement for restoration by grade

3.2.1.5. Comparison of mean kappa values for periodontal conditions by grade

Figure 23 illustrates the results of comparing the kappa values for periodontal conditions by grade. In general, no statistically significant differences were observed between the control and experimental groups (0.03 and 0.06, respectively; p = 0447). The upper 30% subgroups did not show a statistically significant difference with 0.18 and 0.21 (p = 0.818), although the experimental group showed a slightly higher percent agreement. The middle 40% and lower 30% subgroups scored very low in mean kappa values with –0.01 and 0.00 (p = 0.050) and –0.08 and –0.01 (p < 0.001), respectively, although the experimental group performed better with statistical significance (Table 14).

Table 14. Mean kappa values for periodontal condition by grade

Periodontal condition	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.1831	0.1591	0.2072	0.2872	0.819
Middle 40%	36	-0.0064	0.0121	0.0000	0.0000	0.050
Lower 30%	28	-0.0847	0.0325	-0.0053	0.0166	<0.001
Total	92	0.0286	0.1361	0.0577	0.1764	0.447

S.D.: Standard deviation
*p-values calculated using independent sample t-test

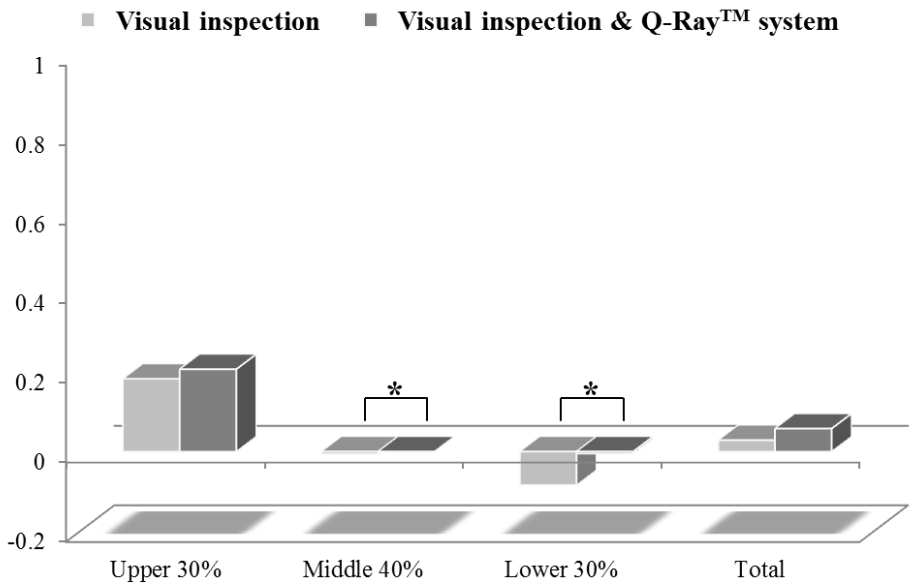

Figure 23. Compared mean kappa value for periodontal condition by grade

3.2.1.6. Comparison of percent agreements for periodontal conditions by grade

Figure 24 gives an overview of the mean percent agreements for periodontal conditions obtained by each subgroup. As outlined in Table 15, the upper 30%, middle 40%, and lower 30% subgroups for the control and experimental groups performed as follows: in the upper 30% subgroups, the experimental group scored higher, but without statistical significance (79.6% vs. 63.2%; p = 0.060); in the middle 40% subgroups, the experimental group outperformed the control groups (61.7% vs. 54.0%; p = 0.429); in the lower 30% subgroups, the control group slightly outperformed the experimental group, but without statistical significance (59.5% vs. 51.8%; p = 0.538). The overall percent agreements were 58.2% and 64.0% (p = 0.339).

Table 15. Mean percent agreement for periodontal condition by grade

Periodontal condition	N	Visual inspection		Visual inspection & Q-Ray™ system		P-values*
		Mean	S.D.	Mean	S.D.	
Upper 30%	28	0.6322	0.2387	0.7964	0.0997	0.060
Middle 40%	36	0.5405	0.3262	0.6167	0.1694	0.429
Lower 30%	28	0.5952	0.2342	0.5179	0.2951	0.538
Total	92	0.5820	0.2749	0.6398	0.2221	0.339

S.D.: Standard deviation
*p-values calculated using independent sample t-test

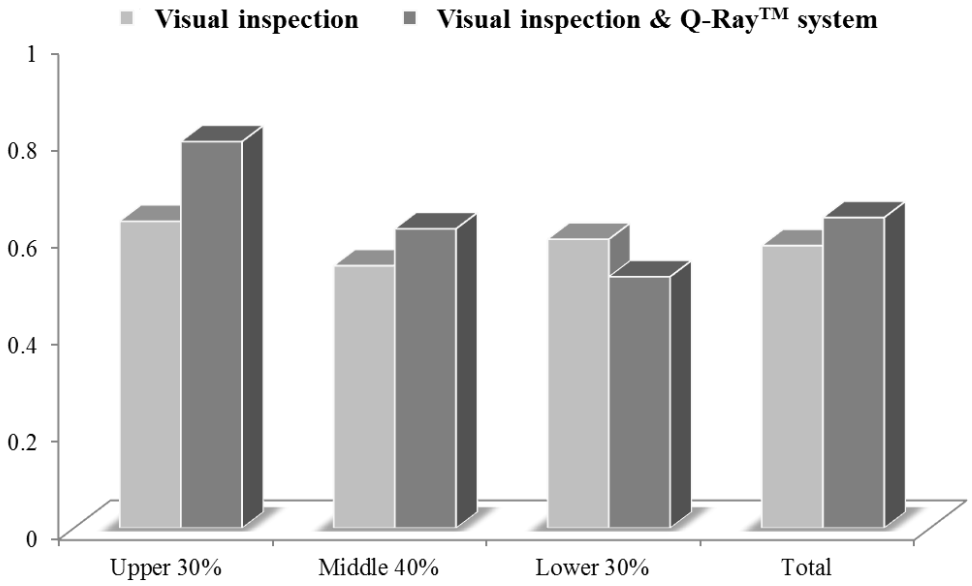

Figure 24. Compared mean percent agreement for periodontal condition by grade

3.2.2. Assessment accuracy by item

3.2.2.1. Comparison of percent agreements by type of lesion

A total of 2267 teeth were assessed to have lesions, of which 2056 were sound teeth. The control group that did not use the Q-Ray view outperformed the experimental group that used it with statistical significance (79.5% vs. 71.3%; $p < 0.001$).

The total number of teeth to be assessed as incipient caries was 21, and the percent agreements of the control and experimental groups were 14.3% and 42.9%, with the experimental group showing a higher degree of agreement, but without statistical significance ($p = 0.147$).

A total of 190 teeth were classified as caries, and the percent agreements of the control and experimental groups were 51.4% and 60.0% ($p = 0.250$) (Table 16) (Figure 25).

Table 16. Percent agreement for tooth status by type of lesion

Lesion	N	Visual inspection	Visual inspection & Q-Ray™ system	P-values*
Sound	2056	79.5%	71.3%	<0.001
Incipient caries	21	14.3%	42.9%	0.147
Caries	190	51.4%	60.0%	0.250
Total	2267			

*p-values calculated using two-sample test of proportions.

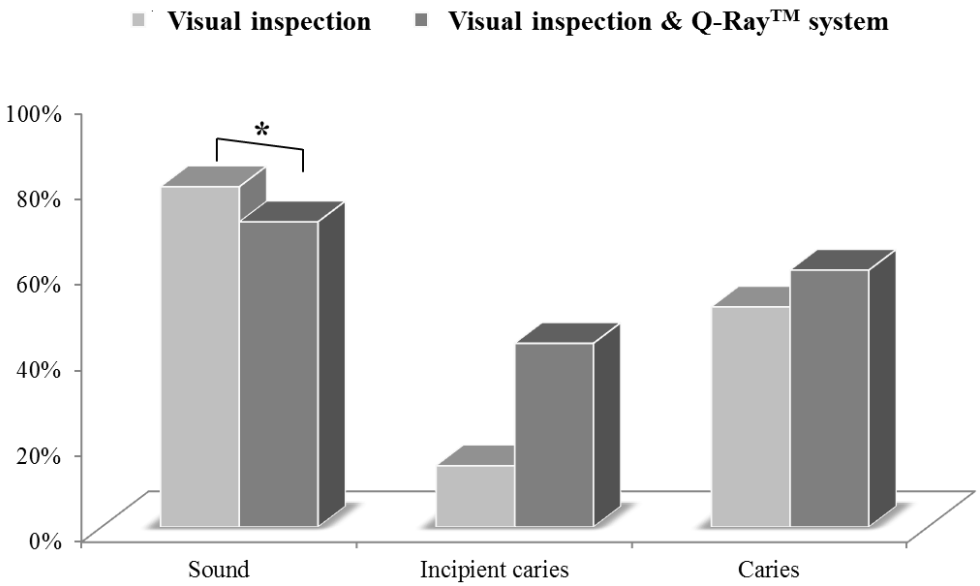

Figure 25. Comparison of percent agreements between two methods for tooth status by type of lesion

3.2.2.2. Comparison of percent agreements by type of restoration

Of the 2267 teeth assessed to be restorations, 1457 were sound teeth, and both control and experimental groups demonstrated high mean percent agreements with 96.0% and 94.6%, respectively ($p = 0.220$).

The total number of amalgams was 157, and the percent agreements of the control and experimental groups were 95.2% and 93.9%, showing no significant difference ($p = 0.751$).

The total number of teeth assessed to be composite resin was 430, and the percent agreements of the control and experimental groups were 42.9% and 66.0%, thus demonstrating that Q-Ray view is effective in detecting composite resin for esthetic ceramic restorations ($p < 0.001$).

The total number of gold inlay cases was 75, and the mean percent agreements of the control and experimental groups were 82.6% and 78.8%. The same for gold crowns ($n = 54$) were 35.5% and 78.3%, showing a significant difference ($p = 0.002$).

There were a total of 60 porcelain crowns, and the experimental group outperformed the control group (64.7% vs. 53.8%), thus demonstrating that the use of Q-Ray view yielded higher assessment accuracy with the gold standard, but without statistical significance ($p= 0.395$).

As regards sealant, no intergroup difference was observed, with 46.2% and 38.1% ($p = 0.643$) (Table 17) (Figure 26).

Table 17. Percent agreement for tooth status by type of restoration

Restoration	N	Visual inspection	Visual inspection & Q-Ray™ system	P-values*
Sound	1457	96.0%	94.6%	0.220
Amalgam	157	95.2%	93.9%	0.751
Composite	430	42.9%	66.0%	<0.001
Gold inlay	75	82.6%	78.8%	0.707
Gold crown	54	35.5%	78.3%	0.002
Porcelain crown	60	53.8%	64.7%	0.395
Sealant	34	46.2%	38.1%	0.643
Total	2267			

*p-values calculated using two-sample test of proportions.

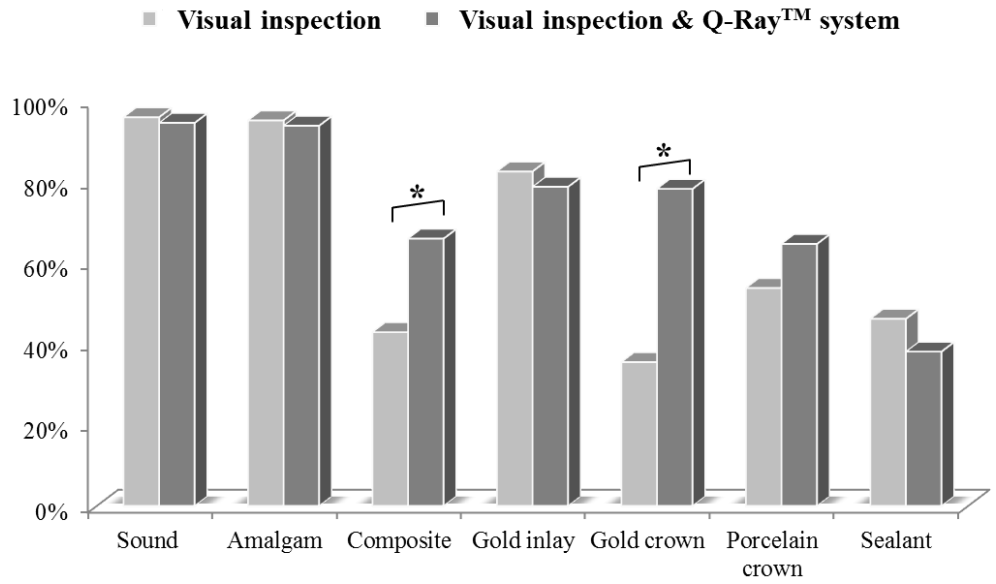

Figure 26. Comparison of percent agreements between two methods for tooth status by type of restoration

3.2.2.3. Comparison of percent agreements by type of periodontal condition

A total of 2267 teeth were to be assessed for periodontal condition. Of these, 2099 were sound teeth, and the control group that did not use the Q-Ray view slightly outperformed the experimental group that used Q-Ray view (63.0% vs. 60.1%; p = 0.185).

A total of 92 teeth were detected to have dental plaque, and the control group outperformed the experimental group, but without reaching statistical significance (33.3% v. 15.0%; p = 0.111).

The total number of dental calculus sites was 76, and the control group was outscored by the experimental group in the degree of agreement, but without statistical significance (48.1% vs. 66.7%; p = 0.131) (Table 18) (Figure 27).

Table 18. Percent agreement for tooth status by type of periodontal condition

Periodontal condition	N	Visual inspection	Visual inspection & Q-Ray™ system	P-values*
Sound	2099	63.0%	60.1%	0.185
Plaque	92	33.3%	15.0%	0.111
Calculus	76	48.1%	66.7%	0.131
Total	2267			

*p-values calculated using two-sample test of proportions.

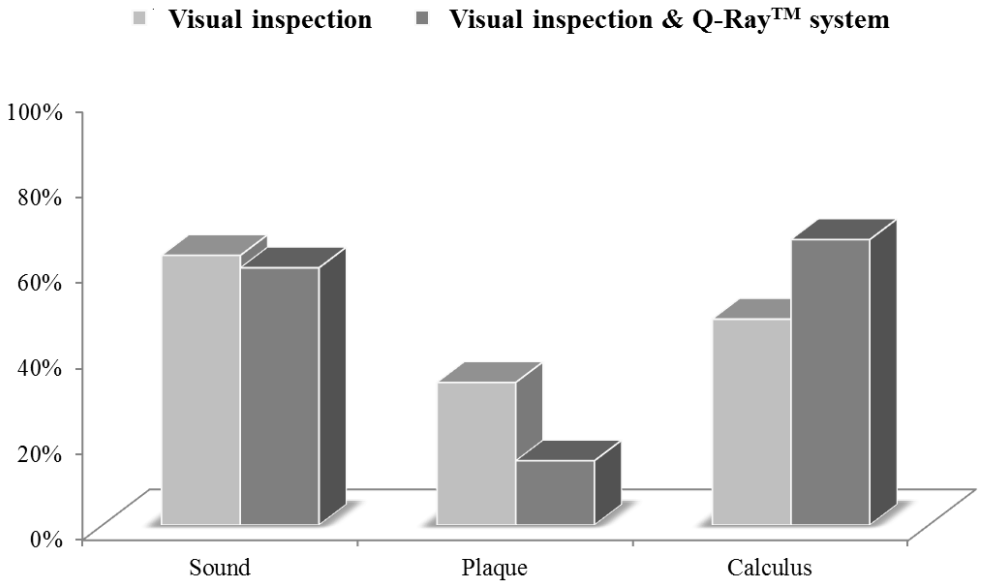

Figure 27. Comparison of percent agreements between two methods for tooth status by type of periodontal condition

IV. DISCUSSION

This study was conducted to evaluate the accuracy of the assessments assisted by the Q-Ray^{TM} system in dental hygiene assessment, the first stage of the dental hygiene process of care, in terms of detecting tooth lesions, restorations, and periodontal conditions and to find out whether the use of the Q-Ray^{TM} system influences the assessment accuracy of dental hygiene students. To this end, the recruited students' assessment accuracies were tested and compared in a series of experiments with an experimental group that used the Q-Ray^{TM} system and a control group that did not, by dividing each group into three subgroups of upper, middle, and lower performance grades.

While no significant differences were observed in the tooth lesion assessment results in the upper grade students of both groups, kappa values showed peculiar patterns. In image test, both experimental and control groups demonstrated kappa values in the middle range of 0.62 or higher. In the simulated patient test, however, the students showed much reduced kappa values of 0.44 (experimental group) and 0.35 (control group). Moreover, while middle and lower grade students showed relatively high kappa values in the image test, they scored very low in the simulated patient test.

The upper grade students of the experimental group attained a significantly higher mean kappa value than those of the control group in the assessment of restorations in the image test (0.85 vs. 0.77; $p = 0.003$). In the simulated patient test, the kappa values were 1.00 and 0.95, with the experimental group slightly outperforming the control group, thereby demonstrating that the use of Q-Ray^{TM} system can enable 100% agreement with the gold standard ($p = 0.076$).

In the assessment of periodontal conditions inspecting the state of dental plaque and

dental calculus, the experimental and control groups obtained mean kappa values of 0.42 and 0.41 in the image test, and 0.21 and 018 in the simulated patient test. While no statistically significant intergroup differences were observed in both test methods, here again, much lower kappa values were obtained in the simulated patient test compared to the image test.

Bordage (1999) noted that sufficient opportunities of practicing and being given feedback should be provided to dental hygiene students in earlier semesters to solve the problem of misdiagnosis. The kappa values, which tended toward strong decrease in the simulated patient test compared to the image test in the assessment of tooth lesions and periodontal conditions, were higher in the simulated patient than the image test in the assessment of restorations. This is assumed to be the feedback-mediated learning effect of the 4-h simulation training prior to the experiment and the image test administered earlier, especially for the upper grade students. Although no significant differences were observed between the experimental and control groups in the assessment of tooth lesions and periodontal conditions, improvement of assessment accuracy may be expected through a more intensive simulation training and clinical evaluation process.

Upper grade students are also known to demonstrate higher clinical implementation abilities (Koh and Park, 2009). The results of this study revealed that upper grade students outperform middle and lower grade students in the assessment accuracy in both image and simulated patient tests. However, the fact that the upper grade students obtained lower kappa values in the simulated patient test compared to the image test in the same manner as the middle and lower grade students implies that more practical training using simulated or real clients is necessary to improve students' assessment abilities (Palomba and Banta, 1999).

The use of the Q-Ray^{TM} system was particularly effective in improving the accuracy of the middle and lower grade students rather than the upper grade students in the assessment of restorations and periodontal conditions. In the practical training relating to dental hygiene process of care, the middle and lower grade students who tend to show a lack of interest in the practical training due to the difficulties in distinguishing lesions or restorations may have found the devices of the Q-Ray^{TM} system, such as QLF-D or Q-Ray view, interesting. When reporting their study results, Komolpis and Johnson (2002) noted that the use of simulation graphic image arouses interest in clinical training reported. In fact, throughout the process of the prior training and image test using QLF-D-captured images, as well as during the simulated patient test using the Q-Ray view, the students showed enthusiasm. Interest in and attention to lectures reportedly have a positive impact on the improvement of academic achievements and scores (So, 2008). The positive effect of the Q-Ray^{TM} system as verified by the improved assessment accuracy in this study may be explained by the effect of arousing students' curiosity about the new devices through the 4-h simulation session with QLF-D-captured images as a prior training and evaluation process.

When capturing images, QLF-D simultaneously provides white images, which are not different from normal digital cameras (DSLR), and blue images manifesting fluorescence emitted from tooth lesions or dental plaque and calculus different from that of natural teeth (Pretty et al., 2003; Coulthwaite et al., 2006). These different images are likely to have offered the less experienced low-semester students additional cues for distinguishing restorations and periodontal conditions. It was reported that conventional and novel methods should be combined to help low-semester students detect and diagnose lesions (Adeyemi et al., 2008). In fact, it is a great challenge for inexperienced

low-semester students to distinguish lesions and restorations with conventional methods alone. The use of the Q-Ray^{TM} system along with the visual inspection must have helped the students in this study distinguish restorations or the state of dental plaque and dental calculus more clearly.

To achieve a high degree of accuracy in assessing lesions, restorations, and periodontal conditions, it is essential to train the students using simulation or real-life cases or relevant products in the undergraduate years (Palomba and Banta, 1999). Combining the cutting-edge technologies with the conventional inspection methods increases the reliability of dental hygiene assessment (Patel et al., 2014) and the use of simulation is effective in reducing errors and achieving training targets, and thus recommendable as the ideal educational method (Littlefield et al., 2003). The results of this study verified the effect of the Q-Ray^{TM} system on the improvement of assessment accuracy, albeit not to any considerable extent, via a 4-h simulation session as well as image and simulated patients tests. Continuous use of the Q-Ray^{TM} system in the clinical implementation and evaluation for dental hygiene process of care is considered to contribute to improving students' assessment accuracy.

The analysis of the percent agreements by type of restoration revealed that in the image test, the experimental group utilizing the Q-Ray^{TM} system attained 84.4% in identifying sound teeth as such, 62.6% in detecting composite resin for esthetic ceramic restorations, and 78.3% in detecting porcelain crowns, thereby demonstrating that the additional use of the Q-Ray^{TM} system contributes to increasing the accuracy in assessing esthetic ceramic restorations as such, compared to the control group that assessed them by visual inspection alone. In the identification of amalgam and gold inlay or gold crowns, no intergroup differences were observed, both groups showing mean percent agreements

of 90% or higher.

In the simulated patient test, no intergroup difference was observed in identifying sound teeth as such, with both groups showing 95% or higher. In the assessment of composite resin for esthetic ceramic restorations, the experimental group using the Q-Ray^{TM} system significantly outperformed the control group (66.0% vs. 42.9%; $p < 0.001$), as in the image test. In contrast, the control group that did not use the Q-Ray^{TM} system outperformed the experimental group that used the Q-Ray^{TM} system in the identification of porcelain crowns, but without statistical significance, unlike in the image test (64.7% vs. 53.8%; $p = 0.395$). As for amalgam and gold inlay, no intergroup differences were observed. In the case of gold crowns, a surprisingly large difference in percent agreements was shown between the experimental (78.3%) and control (35.5%) groups ($p = 0.002$). This is assumed to have occurred by charting error of confusing it with porcelain crown (listed just beneath gold crown) when inputting the results directly into the online survey server SurveyMonkey via smartphone in the simulated patient test.

In the dental hygiene process of care, assessing restorations is an indispensable process for ensuring a continuous monitoring of fine changes around restorations and their systematic management (Amaechi and Higham, 2002). The assessment of amalgam or gold inlay restorations clearly distinguishable from sound teeth yielded percent agreements of 90% or higher by visual inspection alone in both test methods. In the identification of composite resin or porcelain crown using teeth-like colors, however, visual inspection alone showed percent agreements of 60% or lower in both test methods. Obviously, less experienced low-semester students have considerable difficulty in distinguishing esthetic restorations from natural teeth by visual inspection alone.

The students who participated in this study were low-semester students with no experience of client training, but they completed two semesters of basic dental hygiene process of care courses consisting of theory and mutual training offered in the first year second semester and the second year first semester. The optimal way of improving students' assessment accuracy is executing more intensive client practices and confronting more real-life cases. However, it is unrealistic to implement this ideal way of improving the clinical abilities; given the current lack of clients, they can provide real-life cases and train instructors who can transmit skills in hands-on practice settings (Weaver et al., 2001; Han et al., 2009). Direct observation of clients has more reliable educational effects, but previous studies reported that simulation training reproducing real-life cases can have similar learning effects (Kramer, 2002). From the results of the current study, it can also be concluded that it is considered recommendable to develop a systemized simulation training course by expanding the simulation training mediated by the Q-Ray^{TM} system.

The QLF, the first-generation device of the Q-Ray^{TM} system, was developed to detect and diagnose early caries (de Josselin de Jong et al., 1995); it is known to be 10-fold more effective than visual inspection in the detection of demineralized lesions (al-Khateeb, Oliveby et al., 1997; al-Khateeb, ten Cate et al., 1997). Not only can the QLF effectively detect early caries that cannot be easily detected by visual inspection, it can also quantify the degree of demineralization and thus carry out long-term monitoring of fine changes of caries progress and remineralization (Amaechi and Higham, 2002), and Tranaeus et al. (2001) reported on the excellent reproducibility of the QLF.

As if to defy such advantages of the Q-Ray^{TM} system, except for the significant difference in the percent agreement between the middle and low grade students of the

experimental and control groups (64.1% vs. 62.1%) in the assessment of tooth lesions in the image test, no differences were observed between the experimental group that used the Q-Ray^{TM} system and the control group that did not. Moreover, low grade students scored very low kappa values in the image test, as did the middle and low grade students in both image and simulated patient test, unlike the upper grade students, in both experimental and control groups. The performance level of the upper grade students can be considered to be representing the level expected of dental hygiene students upon completion of two semesters' training. The low performance level of the middle and low grade students, however, indicates students lacking abilities and the necessity of taking appropriate measures to enhance their abilities. In this context, it is significant to note that, except for the assessment of tooth lesions as described above, the middle and lower grade students of the experimental group using the Q-Ray^{TM} system obtained significantly higher kappa values and percent agreements in the assessment of restorations and periodontal conditions, whereas the upper grade students were less influenced by the use of the Q-Ray^{TM} system.

Adeyemi et al. (2008) emphasized the usefulness of the QLF not only as a tool for recognizing and detecting early caries, but also for acquiring early caries-related clinical skills and as a non-invasive chair-side method for diagnosing and managing early caries. Taking the results of the current study and the reports of the literature, the Q-Ray^{TM} system is expected to contribute to enhancing the assessment accuracy of middle and low grade students, also in the assessment of tooth lesions, by providing them with continuous training and feedback, as demonstrated by the improved assessment results of the middle and low grade students of the current study in the assessment of restoration and periodontal conditions.

The analysis of the assessment results of tooth lesion by item revealed that in the image test, the experimental group using the Q-Ray^{TM} system showed a higher average percent agreement than the control group not using the Q-Ray^{TM} system with statistical significance (85.9% vs. 71.6%; $p < 0.001$) in identifying sound teeth as such. In contrast, in detecting incipient caries and caries, the control group outscored the experimental group (39.1% vs. 23.9% and 57.3% vs. 46.9%, respectively; $p > 0.001$), thus demonstrating that the use of the Q-Ray^{TM} system had a negative effect on the assessment of carious lesions. In the simulated patient test, unlike in the image test, the difference was shown only in identifying sound teeth, wherein the control group outperformed the experimental group with statistical significance (79.5% vs. 71.3%; $p < 0.001$). The fact that sound teeth can be assessed as such using the Q-Ray^{TM} system in the image test implies that the likelihood of identifying lesions, such as early caries, as such is also high under the aspect of sensitivity and specificity (Gomez et al., 2013). However, the actual results were contradictory to this reasoning. This is assumed to be attributable to the substantially low prevalence of lesions compared to sound teeth. In particular, in the simulated patient test, while no intergroup differences were observed regarding lesions such as incipient carious lesions and caries, the control group obtained a higher mean percent agreement ($p < 0.001$). This is considered to be associated with insufficient lesion cases as a result of largely reduced prevalence of incipient caries (Marthaler, 2004) although much effort was made to ensure enough cases of lesions by recruiting students with at least two lesions or restorations as simulated patients. As another causative factor, the possibility cannot be ruled out that the simulated patients who mimic real-life clients might have acted as various confounders in the assessment process. Furthermore, the low-semester students, who are not even familiar with handling a dental mirror, participated

for the first time in client practice and had to use additionally the Q-Ray view, a totally new device. As still another reason, saliva or dental plaque can be considered. Amaechi and Higham (2002) state that the QLF is an excellent device for long-term monitoring of the remineralization process of early caries, but has a limited ability in detecting tooth lesions due to saliva or dental plaque. In this study, in order to assess dental calculus or dental plaque, the simulated patients were not given oral prophylaxis prior to the simulated patient test. It is highly probable that this acted as a disturbing factor in assessing lesions. Another hurdle was that unlike the image test, in which only the captured images were inspected, the simulated patient test involved the complete intraoral regions and dental arches, which may have dissipated students' concentration in the assessment process. All these variables are considered to have affected the tooth lesion assessment of less experienced low-semester students, especially of less skilled middle and low grade students.

The middle and low grade students in the experimental group using the Q-Ray^{TM} system outscored their counterparts in the control group in the assessment of restorations in both kappa values and percent agreements. In the image test, both middle and low grade students obtained higher kappa values than their control group counterparts with statistical significance (0.71 vs. 0.60 and 0.54 vs. 0.42; $p < 0.001$ and $p = 0.009$, respectively). In the simulated patient test, similar results were obtained with 0.75 vs. 0.65 for the middle grade students and 0.49 vs. 0.30 for the lower grade students ($p = 0.008$ and $p < 0.001$, respectively).

A simple analysis was performed on the wrong answers in the lesion assessment. In many cases, esthetic restorations were misidentified as sound teeth and sound teeth were mistaken for incipient caries. In fact, it is difficult to distinguish refined esthetic ceramic

restorations from sound teeth and the subtle color changes of old ceramic restorations differing from that of natural teeth may have been mistaken for incipient caries.

Previous studies reported that QLF-D can quantify demineralization-induced fine changes occurring around a restoration (Ando et al., 2001; Pretty et al., 2003). Harrington (1979) stressed the necessity for a clear assessment standard for accurate diagnosis of tooth lesions or restorations for the prevention of oral diseases and systematic management of oral health. The QLF-D recently evolved from the QLF not only detects incipient caries, but also distinguishes composite resin for esthetic ceramic restorations by inducing white or yellow color emissions different from natural teeth (Tani et al., 2003; Meller and Klein, 2012). The QLF-D is therefore considered a reliable device applicable as a diagnostic tool capable of providing a clear assessment standard.

The analysis of the assessment results for dental plaque and dental calculus as items for assessing periodontal conditions revealed that the middle and lower grade students showed much lower kappa values in both groups compared to the upper grade students. In the intergroup comparison of the middle and lower grade students, the experimental group showed significantly higher accuracy. In the image test, the mean kappa value of the middle grade students was significantly higher than that of their control group counterparts who did not use the Q-Ray^{TM} system (0.29 vs. 0.13; $p < 0.001$). The lower grade students scored very low, demonstrating extremely low assessment accuracy, but there was a significant difference between using and not using the Q-Ray^{TM} system (0.15 vs. 0.02; $p < 0.001$). The kappa values among the middle and lower grade students were even lower in the simulated patient test, but those in the experimental group who used the Q-Ray^{TM} system showed significantly higher kappa values compared to their counterparts in the control group (0.00 vs. –0.01; $p = 0.050$ for middle grade and –0.08 vs. –0.01; $p <$

0.001 for the lower grade).

The purpose of assessing dental plaque or dental calculus in the dental hygiene process of care is to accurately evaluate the oral health status and periodontal conditions and provide a systematic oral health management program in order to prevent incipient caries or periodontitis. Dental plaque and dental calculus are major causes of periodontal diseases (Axelsson and Lindhe, 1981; Christersson et al., 1992) and can be prevented by implementing a systematic prevention and management program.

With the Q-ray™ system, dental plaque can be detected without the need for staining, because it can induce the autofluorescence of endogenous porphyrins generated by the intraoral microbial biofilm; in particular, mature microbial dental plaque is known to emit intense red fluorescence (Coulthwaite et al., 2006; Hope et al., 2011; Kim et al., 2014). Although mature dental plaque stained with 2-tone disclosing solution discharges blue color (Block et al., 1972) and has the educative effect of impressing and motivating the clients toward better dental care, its disadvantages, such as staining clothes and skin and the traces remaining in the oral cavity after the application, can cause inconvenience for dentists and clients. Therefore, the use of the Q-ray™ system that can quantify dental plaque without using staining agents is expected to contribute to bringing more efficacy to the entire dental hygiene process.

In 1998, the American Dental Association (ADA)'s Commission on Dental Accreditation (CODA) introduced a dental hygiene program designed to develop the achievement target and competency required of last-semester students and pointed out that the standards for dental hygiene education programs should serve as criteria for patient care competencies and educational program evaluation (Lane and Gottlieb, 2004;

Fjortoft, 2006). To achieve this objective, a sufficient number of subject clients offering various cases and trainers should be provided, but it is extremely difficult to recruit clients to satisfy the training needs matching the dental hygiene curriculum (Navickis et al., 2010).

The simulation training session prior to the image and simulated patient tests using the Q-ray™ system proved to be conducive to improving the students' assessment performance. Simulation training has become integrated into the education in the disciplines in medicine and nursing, and more recently dentistry (Issenberg et al., 1999; Buchanan, 2001; Bremner et al., 2006; Foster et al., 2008). Meyer et al. reported in their study results that the students who had received simulation training could improve their clinical skills more rapidly and sustainably than the students who had not (Meyer et al., 2011). Buchanan (2001) noted that simulation training improves students' academic achievements and clinical skills and provides teachers with interesting aids to arouse and satisfy students' appetite for learning. Kraemer and Gurenlian (1989) asserted that a dental hygiene curriculum focusing on broadening theoretical scope and depth and enriching clinical experience would improve the clinical application of their knowledge and enhance clinical decision-making skills after graduation.

In the current study, instead of real-life clients, we used image simulation and patient simulation. However, simulation training has not yet been generalized in the field of dental hygiene in which the mostly widely used training model is a dentiform. Moreover, assessment methods are taught on the basis of conventional visual inspection even in clinical practice with real patients, which does not always allow accurate and objective diagnosis (Barnes, 2005). If the Q-ray™ system is used for simulation training in tandem with the conventional dental assessment instead of using real case patients, it will also be

effective as feedback to visual inspection through repetitive training, as demonstrated by the results of the current study.

According to the results of the current study, the use of the Q-ray™ system increased the assessment accuracy of the middle grade students in the assessment of lesions and of the upper, middle, and lower grade students in the assessment of restorations and periodontal conditions in the image test. In the simulated patient test, the use of the Q-ray™ system improved the assessment accuracy in the assessment of restorations and periodontal conditions by the middle and lower grade students. Taken together, the use of the Q-ray™ system is considered to be useful in improving the efficacy in the overall dental hygiene process of care.

The following may be pointed out as limitations. First, despite the efforts to ensure an even distribution of lesions and restorations when recruiting the subjects for the simulated patients, the post-test analysis revealed that the prevalence of lesions, restorations, and periodontal conditions was too low with respect to sound teeth, and it is highly probable that this imbalance influenced the kappa values and percent agreements of the experimental and control groups. For future studies, to overcome this limitation, it is proposed to select simulated patients with more lesions and restorations and limit the inspection to teeth with lesions and restorations, as is the case with the image test.

Second, in order to use the online survey service for the simulated patient test, answers were directly inputted into the server via smartphone. This saved time and personnel for extra coding, but it cannot be ruled out that errors occurred when touching the checkboxes for the intended answers, such as touching the adjacent boxes or multiple boxes at the same time. Such limitations can be addressed by designing the input chart

taking into account possible error sources.

Third, in the image test, the control group that did not use the Q-ray™ system scored higher in the percent agreement. This is assumed to be caused by the same time limit of 30 s per slide imposed on both groups. More time should have been allowed for the experimental group taking into consideration that the experimental group had to inspect two images (white image of the slide and blue image of the system) while the control group had only to inspect the slide image.

In future studies, the study design should be improved by addressing these limitations on the basis of the study results. A longitudinal study is also considered necessary to evaluate the long-term effects of using the Q-Ray™ system. Applied to this study, long-term follow-up monitoring of the assessment accuracy of the students in the experimental group under the continuous use of the Q-Ray™ system is advisable.

V. CONCLUSION

This study was conducted to evaluate the assessment accuracy of dental hygiene students who participated in practical training for dental hygiene process of care for the first time, in the assessment of lesions, restorations, and periodontal conditions using the Q-Ray™ system. Their test results were converted into kappa values and percent agreements after being checked against the gold standards established by skilled dental hygienists. From the analysis of the study results, the following key facts may be summarized as the conclusion of this study.

First, a statistically significant difference was found in the percent agreements for tooth lesions between the middle grade subgroups of the experimental group that used the Q-Ray™ system and the control group that did not (64% vs. 62%; $p = 0.043$).

Second, in the assessment of restorations, all students in the upper, middle, and lower grade subgroups in the experiential group significantly outperformed their counterparts in the control group in the image test in terms of kappa values and percent agreements, thus demonstrating that the use of the Q-Ray™ system enhances the detection accuracy for restorations. In the simulated patient tests, only the students of middle and lower grade subgroups of the experimental group obtained higher kappa values and percent agreements.

Third, the analysis of the differences by type of restoration revealed that the experimental group using the Q-Ray™ system showed high percent agreements for composite resin (for esthetic ceramic restorations) and porcelain crowns in the image test, while similarly high percent agreements were obtained by the experimental group for composite resin and gold crowns in the simulated patient test.

Fourth, in the assessment of periodontal conditions by inspecting dental plaque and dental calculus, middle and lower grade subgroups of the experimental group using the Q-Ray™ system showed higher kappa values in both image and simulated patient tests.

The results of this study verified the effects of the Q-Ray™ system in improving the assessment accuracy in the dental hygiene process of care and enhancing students' assessment performance. Therefore, it is proposed that the Q-Ray™ system should be integrated into the overall training curriculum of the dental hygiene process of care.

REFERENCES

Adeyemi AA, Jarad FD, Komarov GN, Pender N, Higham SM: Assessing caries removal by undergraduate dental students using quantitative light-induced fluorescence. J Dent Educ 72(11): 1318-1323, 2008.

Alammari MR, Smith PW, de Josselin de Jong E, Higham SM: Quantitative light-induced fluorescence (QLF): a tool for early occlusal dental caries detection and supporting decision making in vivo. J Dent 41(2): 127-132, 2013.

al-Khateeb S, Oliveby A, de Josselin de Jong E, Angmar-Mansson B: Laser fluorescence quantification of remineralisation in situ of incipient enamel lesions: influence of fluoride supplements. Caries Res 31(2): 132-140, 1997.

al-Khateeb S, ten Cate JM, Angmar-Mansson B, de Josselin de Jong E, Sundstrom G, Exterkate RA, et al.: Quantification of formation and remineralization of artificial enamel lesions with a new portable fluorescence device. Adv Dent Res 11(4): 502-506, 1997.

Amaechi BT, Higham SM: Quantitative light-induced fluorescence: a potential tool for general dental assessment. J Biomed Opt 7(1): 7-13, 2002.

Ando M, van Der Veen MH, Schemehorn BR, Stookey GK: Comparative study to quantify demineralized enamel in deciduous and permanent teeth using laser- and light-induced fluorescence techniques. Caries Res 35(6): 464-470, 2001.

Association ADE: Competencies for entry into the profession of dental hygiene. Journal of Dental Education 68(7): 745-749, 2000.

Axelsson P, Lindhe J: Effect of controlled oral hygiene procedures on caries and periodontal disease in adults. Results after 6 years. J Clin Periodontol 8(3): 239-248, 1981.

Barnes CM: Dental hygiene participation in managing incipient and hidden caries. Dent Clin North Am 49(4): 795-813, vi-vii, 2005.

Bjelkhagen H, Sundstrom F: A clinically applicable laser luminescence method for the early detection of dental caries. Quantum Electronics, IEEE Journal of 17(12): 2580-2582, 1981.

Bordage G: Why did I miss the diagnosis? Some cognitive explanations and educational implications. Acad Med 74(10 Suppl): S138-143, 1999.

Bremner MN, Aduddell K, Bennett DN, VanGeest JB: The use of human patient simulators: Best practices with novice nursing students. Nurse Educator 31(4): 170-174, 2006.

Buchanan JA: Use of simulation technology in dental education. Journal of Dental Education 65(11): 1225-1231, 2001.

Christersson LA, Grossi SG, Dunford RG, Machtei EE, Genco RJ: Dental plaque and calculus: risk indicators for their formation. J Dent Res 71(7): 1425-1430, 1992.

Coulthwaite L, Pretty IA, Smith PW, Higham SM, Verran J: The microbiological origin of fluorescence observed in plaque on dentures during QLF analysis. Caries Res 40(2): 112-116, 2006.

Darby ML, Walsh MM: Dental hygiene : theory and practice. 3rd ed. Saunders/Elsevier, St. Louis, Mo, 2015, p. 13-25.

de Josselin de Jong E, Sundstrom F, Westerling H, Tranaeus S, ten Bosch JJ, Angmar-Mansson B: A new method for in vivo quantification of changes in initial enamel caries with laser fluorescence. Caries Res 29(1): 2-7, 1995.

Fitch P: Cultural competence and dental hygiene care delivery: integrating cultural care into the dental hygiene process of care. J Dent Hyg 78(1): 11-21, 2004.

Fjortoft N: Self-assessment in pharmacy education. Am J Pharm Educ 70(3): 64, 2006.

Foster JG, Sheriff S, Cheney S: Using nonfaculty registered nurses to facilitate high-fidelity human patient simulation activities. Nurse Educ 33(3): 137-141, 2008.

Gomez J, Tellez M, Pretty IA, Ellwood RP, Ismail AI: Non-cavitated carious lesions detection methods: a systematic review. Community Dent Oral Epidemiol 41(1): 54-66, 2013.

Harrington GW: The perio-endo question: differential diagnosis. Dent Clin North Am 23(4): 673-690, 1979.

Han SY, Kim NH, Yoo JH, Kim CS, Chung WG: Current status of clinical dental hygiene education based on dental hygiene process of care. J Dent Hyg Sci 9(3): 271-278, 2009.

Hawley N, Dye J, Ditmyer M: Knowledge, attitudes, and perceptions of participants and instructors taking part in a dental school simulation course for potential dental students. J Dent Educ 73(4): 483-489, 2009.

Hope CK, de Josselin de Jong E, Field MR, Valappil SP, Higham SM: Photobleaching of red fluorescence in oral biofilms. J Periodontal Res 46(2): 228-234, 2011.

Issenberg SB, McGaghie WC, Hart IR, Mayer JW, Felner JM, Petrusa ER, et al.: Simulation technology for health care professional skills training and assessment. JAMA 282(9): 861-866, 1999.

Kim HE, Kwon HK, Kim BI: Recovery percentage of remineralization according to severity of early caries. Am J Dent 26(3): 132-136, 2013.

Kim YS, Lee ES, Kwon HK, Kim BI: Monitoring the maturation process of a dental microcosm biofilm using the Quantitative Light-induced Fluorescence-Digital (QLF-D). J Dent 42(6): 691-696, 2014.

Koh SB, Park HJ: The Correlation between the Scores of Written Examination, the Clinical Clerkship Examination, the Clinical Skill Assessment, and the Graduation Examination of the Medical Students. Korean Journal of Medical Education 21(4): 347-352, 2009.

Komolpis R, Johnson RA: Web-based orthodontic instruction and assessment. J Dent Educ 66(5): 650-658, 2002.

Kramer AW, Jansen JJ, Zuithoff P, Dusman H, Tan LH, Grol RP, et al.: Predictive validity of a written knowledge test of skills for an OSCE in postgraduate training for general practice. Med Educ 36(9): 812-819, 2002.

Lane JL, Gottlieb RP: Improving the interviewing and self-assessment skills of medical students: is it time to readopt videotaping as an educational tool? Ambul Pediatr 4(3): 244-248, 2004.

Littlefield JH, Demps EL, Keiser K, Chatterjee L, Yuan CH, Hargreaves KM: A multimedia patient simulation for teaching and assessing endodontic diagnosis. J Dent Educ 67(6): 669-677, 2003.

Lizarelli RF, Bregagnolo JC, Lizarelli RZ, Palhares JM, Villa GE: A comparative in vitro study to diagnose decayed dental tissue using different methods. Photomed Laser Surg 22(3): 205-210, 2004.

Loe H: The Gingival Index, the Plaque Index and the Retention Index Systems. J Periodontol 38(6): Suppl:610-616, 1967.

Marthaler TM: Changes in dental caries 1953-2003. Caries Res 38(3): 173-181, 2004.

Meller C, Klein C: Fluorescence properties of commercial composite resin restorative materials in dentistry. Dent Mater J 31(6): 916-923, 2012.

Mestriner SF, Vinha D, Mestriner Junior W: Comparison of different methods for the occlusal dentine caries diagnosis. J Appl Oral Sci 13(1): 28-34, 2005.

Meyer MN, Connors H, Hou Q, Gajewski B: The effect of simulation on clinical performance: a junior nursing student clinical comparison study. Simul Healthc 6(5): 269-277, 2011.

Navickis MA, Bray KK, Overman PR, Emmons M, Hessel RF, Cowman SE: Examining clinical assessment practices in U.S. dental hygiene programs. J Dent Educ 74(3): 297-310, 2010.

Palomba CA, Banta TW: Assessment essentials : planning, implementing, and improving assessment in higher education. 1st ed. Jossey-Bass Publishers, San Francisco, 1999, p. 115-116.

Patel A, Koshy N, Ortega-Barnett J, Chan HC, Kuo YF, Luciano C, et al.: Neurosurgical tactile discrimination training with haptic-based virtual reality simulation. Neurol Res 36(12): 1035-1039, 2014.

Pretty IA, Smith PW, Edgar WM, Higham SM: Detection of in vitro demineralization adjacent to restorations using quantitative light induced fluorescence (QLF). Dent Mater 19(5): 368-374, 2003.

Shi XQ, Tranaeus S, Angmar-Mansson B: Comparison of QLF and DIAGNOdent for quantification of smooth surface caries. Caries Res 35(1): 21-26, 2001.

So, Y. H. (2008). "The Effects of Achievement Goal Orientation and Self-efficacy on Course Interests and Academic Achievement in Medical Students." Korean Journal of Medical Education 20(1): 37-49.

Stookey G: The evolution of caries detection. Dimensions of Dental Hygiene 10: 12-14, 2003.

Swanson DB, Stillman PL: Use of standardized patients for teaching and assessing clinical skills. Evaluation & the Health Professions 13(1): 79-103, 1990.

Tani K, Watari F, Uo M, Morita M: Discrimination between composite resin and teeth using fluorescence properties. Dent Mater J 22(4): 569-580, 2003.

Tranaeus S, Al-Khateeb S, Bjorkman S, Twetman S, Angmar-Mansson B: Application of quantitative light-induced fluorescence to monitor incipient lesions in caries-active children. A comparative study of remineralisation by fluoride varnish and professional cleaning. Eur J Oral Sci 109(2): 71-75, 2001.

van der Veen MH, Thomas RZ, Huysmans MC, de Soet JJ: Red autofluorescence of dental plaque bacteria. Caries Res 40(6): 542-545, 2006.

Walsh MM, Darby M: Application of the human needs conceptual model of dental hygiene to the role of the clinician : part II. J Dent Hyg 67(6): 335-346, 1993.

Weaver RG, Haden NK, Valachovic RW: Dental school vacant budgeted faculty positions: academic year 2000 - 2001. J Dent Educ 65(11): 1291-1302, 2001.

Weerheijm KL, van Amerongen WE, Eggink CO: The clinical diagnosis of occlusal caries: a problem. ASDC J Dent Child 56(3): 196-200, 1989.

Wenzel A, Larsen MJ, Fejerskov O: Detection of occlusal caries without cavitation by visual inspection, film radiographs, xeroradiographs, and digitized radiographs. Caries Res 25(5): 365-371, 1991.

ABSTRACT(IN KOREA)

치위생과정에서 Q-Ray™ 시스템을 이용한 구강 검사의 역량 평가

<지도교수 김백일>

연세대학교 대학원 치의학과

오혜영

치위생사정(dental hygiene assessment)에서 치아병소나 수복물, 치주태 등의 평가는 전통적인 검사방법인 시진법(visual inspection)을 사용해 왔다. 그러나 경험이 부족한 치위생과 학생은 시진만으로 치아병소나 수복물, 치태나 치석을 구분하는 것 조차 매우 어려운 일이다.

최근 개발된 Quantitative Light induced Fluorescence-digital Biluminator™ (이하 QLF-D, Q-Ray™ system)는 초기치아우식증(incipient caries)이나 치아우식증(dental caries)같은 치아병소를 탐지하는 것 뿐만아니라 자연치아와 유사한 심미수복물의 구분이 가능하고 세균이 생산하는 endogenous porphyrins에 의해 나타나는 붉은 형광의 치태(dental plaque)를 탐지하고 정량화 할 수 있다.

따라서 치위생과 교육과정에서부터 이와 같은 신뢰성 있는 진단장비의

사용으로 다양한 사례의 교육과 훈련이 이루어 진다면 검사의 정확도를 높이고 학생의 검사역량을 향상시킬 수 있을 것이다.

본 연구는 연세대학교 치과대학병원 연구심의위원회(IRB No:2-2014-0023)의 승인을 받아 진행되었다. 치위생사정에서 치아병소, 수복물, 치주상태를 평가할 때 전통적인 검사방법인 시진법(visual inspection)과 Q-Ray™ system과 시진법을 동시에 사용하는 새로운 검사방법의 차이를 gold standard와 비교하여 정확도(accuracy)에 차이가 있는지 알아보았다.

연구대상자는 최초 치위생과정실습에 참여하는 치위생과 학생 110명으로서 검사자는 92명, 모의환자는 18명이었다. 검사자 92명은 각 46명씩 실험군과 대조군으로 무작위 할당되었으며, 모의 환자 18명은 병소와 수복물이 골고루 배분되도록 각 군에 9명씩 임의 할당되었다.

학생이 검사한 결과를 바탕으로 각 군별로 Cohen's kappa 값을 산출하여 학생의 상위 30%, 중위 40%, 하위 30%로 순위를 구분하여 각 군별 순위별로 치아병소와 수복물, 치주상태를 kappa값과 정답률(percent agreement)로 비교하였다.

연구결과 치아병소는 사진평가의 경우만이 중위학생에서 실험군이 64%의 정답률을 나타냈으며 대조군 62%보다 유의한 차이로 높았다(p=0.043).

수복물에서는 사진평가와 모의환자평가 모두 상, 중, 하위 학생에서 실험군이 더 높은 kappa값과 정답률을 나타내 Q-Ray™ system을 사용하는 경우 수복물을 탐지하는 정확도가 향상되는 것으로 나타났다.

수복물의 종류를 알아본 결과 사진평가에서 composit resin의 경우 실험

군과 대조군이 각각 62.6%와 56.0%(p=0.006), porcelain crown은 78.3%와 52.9%(p<0.001)로 Q-Ray^{TM} system 을 사용한 실험군이 더 높은 정답률을 나타냈으며, 모의환자평가에서는 composit resin이 실험군 66.0%, 대조군 42.9%로 실험군이 더 높은 정답률을 보였고 통계적으로 유의한 차이를 나타냈다(p<0.001).

치주상태의 순위별 차이를 알아본 결과 사진평가와 모의환자평가 모두 중위와 하위학생이 실험군에서 더 높은 kappa값과 정답률을 보여 Q-Ray^{TM} system을 사용하는 경우 상위학생보다 중위와 하위학생이 치태나 치석을 탐지하는 정확도가 상승하는 것으로 나타났다.

본 연구의 결과로 치위생사정에서 대상자의 치아 및 치주상태를 평가하는 방법으로 Q-Ray^{TM} system 활용하는 것은 평가의 정확도를 향상시키고 학생의 검사역량 향상에 도움이 될 것으로 기대한다.

핵심되는 말: 치위생과정, 치위생사정, 모의환자, Q-Ray^{TM} system

Appendix

Appendix Figure 1. Information Sheet

연세대학교 치과대학병원 임상시험심사위원회

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별첨 1. 대상자 설명문

대상자 설명문

◆ 큐레이뷰를 활용한 치아검사 역량 증진

(부제: 광학 장비를 활용한 치아 상태 검사 정확성 평가)

이 설명문을 주의 깊게 읽으시기 바랍니다. 본 연구는 연세대학교 치과대학 예방치과학교실에서 진행하는 연구이며 연구의 책임자는 연세대학교 치과대학 예방치과학교실 김백일 교수입니다. 귀하는 이 연구에 관해서 질문 할 수 있는 충분한 시간을 가질 수 있습니다. 연구담당자는 귀하가 명확히 이해하지 못하는 단어나 정보에 대해 충분히 설명드릴 것입니다.

귀하에게 임상연구 참여를 요청합니다. 연구자는 귀하가 본 연구 참여 대상자로 고려될 수 있는 선정 기준에 적합한 것으로 평가하였습니다. 이 임상연구 참여에 동의하시기 전에 귀하는 예정된 절차에 대한 다음의 설명을 읽고 이해하는 것이 중요합니다. 이 설명문에서는 연구의 목적, 절차 및 유해성에 대해 설명하고 있습니다. 또한 귀하는 언제든지 이 연구 참여를 중단할 수 있음을 설명하고 있습니다.

1. 연구 목적

본 연구는 큐레이뷰 (Quantitative light-induced fluorescence-digital, Qray-view)라는 빛을 이용하는 검사 장비가 기존의 치아 검사방법인 눈으로 검사하는 방법(시진)과 비교했을 때 치아 검사의 정확성이 얼마나 향상되는지 평가하고자 합니다. 이를 통해 치위생과 학생들이 치아를 검사할 수 있는 역량이 증진되는데 도움이 될 것입니다.

2. 연구 참여 기간 및 방법

본 연구에 참여하는 모든 대상자는 총 2 회에 걸쳐 방문하시게 되며 첫 번째 방문 후 6 주 뒤 방문하시면 됩니다. 귀하는 치위생 과정 실습에 처음 참여하는 치위생과 학생으로 검사 기기인 큐레이뷰에 대한 원리 및 사용법에 대한 교육을 일정 시간 동안 받게 됩니다. 이후 귀하는 다른 두 가지 검사 방법인 '눈으로 검사하는 집단(시진)' 과 '눈으로 검사하면서 큐레이뷰 장비도 함께 검사하는 집단(시진+Qray-view)' 으로 배정되거나 치아 상태 검사를 받는 '모의 대상자 집단'

이렇게 세 집단 중 하나의 집단으로 임의 배정됩니다. 귀하가 치아를 검사하는 집단에 배정된다면 모의대상자의 치아 검사를 한 후 기록지에 검사 결과를 작성합니다. 이후 귀하가 평가한 검사 결과와 연구담당자 2 명이 평가한 모의 대상자의 치아 검사 결과를 비교합니다. 이를 통해 '큐레이뷰 장비를 사용한 집단'이 치아 검사를 하는데 있어 정확성이 얼마나 향상되는지 평가하는 근거자료로서 활용될 것입니다.

3. 연구 참여에 따른 혜택

이 연구를 통해 귀하는 치아 검사에 대한 정확성이 향상되는 것을 확인할 수 있을 것이며 새로운 장비에 대한 교육을 받을 수 있게 됩니다.

4. 비밀 보장

귀하의 개인정보는 익명으로 처리되어 보관되므로 연구 결과가 연구자에게 전달되는 과정에서도 귀하의 신상을 알 수 있는 정보는 제공되지 않습니다. 대상자의 기록은 기밀로 유지되나, 관련규정 내에서 모니터요원, 점검 및 실태조사를 실시하는 자, 심사위원회는 비밀보장을 침해하지 않는 범위 안에서 신뢰성 검증을 위해 대상자의 의무기록을 직접 열람할 수 있으며 동의서에 서명함이 이러한 열람을 허용한다는 사실을 명시합니다.

5. 임상연구에 참여함으로써 받게 되는 금전적 보상 여부 및 대상자에게 추가적으로 발생되는 비용

귀하께서는 참여하는 과정에 발생되는 시간적 손실에 대한 부분은 이미 동의하시는 것이므로 이로 인한 어떠한 손실도 발생하지 않을 것입니다.

7. 문의 사항

귀하는 연구기간 중 어느 때라도 귀하의 담당자에게 추가 정보를 요청할 수 있습니다. 또한, 귀하가 연구 대상자로서 문의 사항이 있다면 아래 연구 담당자에게 연락하여 주시기 바랍니다.

◆ 연구 책임자: 김백일(연세대학교 치과대학 예방치과학교실), 02-2228-3070

- 연구 담당자

소속: 연세대학교 치과대학 예방치과학교실	
오혜영	02-2228-3070
이형석	02-2228-3070
고혜연	02-2228-3070
정회인	02-2228-3070
구혜민	02-2228-3070

- 연구윤리심의위원회 02-2228-8613

8. 연구 참여 - 연구 참여 철회

귀하의 연구 참여는 전적으로 자발적으로 이루어지며, 원하지 않을 경우 귀하는 언제든지 연구 참여를 중단할 권리가 있습니다. 참여 거절 또는 연구 중단으로 인한 어떠한 불이익이나 의학적 치료의 타협 또는 이익에 대한 권리를 손해 보는 일은 없을 것입니다

확 인 날 짜: 년 월 일

연구 담당자: 인

연락처:

Appendix Figure 2. Informed Consent Form

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※ 별첨 2. 대상자 동의서

대상자 동의서

나는 큐레이뷰를 활용한 치아검사 역량 증진효과 **(부제: 광학 장비를 활용한 치아 상태 검사 정확성 평가)** 라는 주제의 임상연구에 관한 연구 목적, 방법, 기대효과, 가능한 위험성, 채취 방법 및 과정 등에 대한 동의서 내용에 대하여 연구 담당자에게서 충분한 설명을 들어 이해하였습니다. 이에 아래와 같이 본인이 검사한 모의대상자의 치아 상태 검사 기록지를 연구에 이용하는 것에 자발적인 의사로 동의합니다. 본 연구에 동의한 경우라도 언제든지 철회할 수 있음을 확인하였으며, 대상자 설명문 및 동의서 사본 1부를 받을 것을 알고 있습니다.

대상자	성 명	(서명)
	생년월일	년 월 일
	날 짜	년 월 일
대리인	성 명	(서명)
	날 짜	년 월 일
연구 담당자	성 명	(서명)
	날 짜	년 월 일

Appendix Figure 3. SurveyMonkey Chart

치아평가챠트 출생년도_____년 / 반 :_____성함 : _____ (시진군 / 큐레이+시진군)

구분	분류
건전(Sound)	
0	건전(Sound)
병소(lesion)	
1	초기치아우식증(Incipient Caries)
2	치아우식증(Dental Caries)
3	이차우식증(2nd Caries)
4	치아파절(Fracture)
5	치경부마모증(Cervical abrasion)
6	치아교모증(Attrition)
7	상실치아(Missing tooth)
수복(Restoration)	
8	아말감(Amalgam)
9	심미수복제(Resin/Resin, Ceramin inlay)
10	금인레이(Gold inlay)
11	금속관(Gold, Metal Crown)
12	도재관(Pocelain, Ceramic Crown)
13	치면열구전색(Sealant)
치주(Periodontium)	
14	치면세균막(Dental plaque)
15	치석(Dental calculus)
16	착색(Stain)